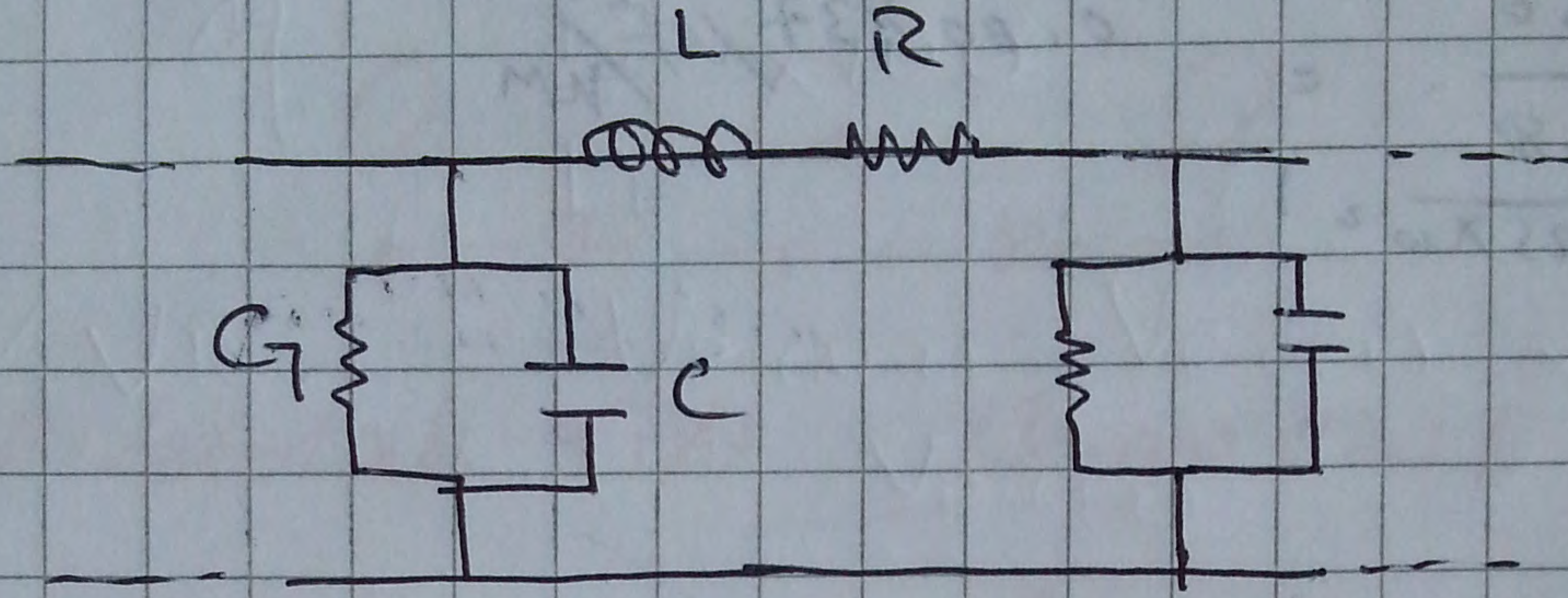
A.G

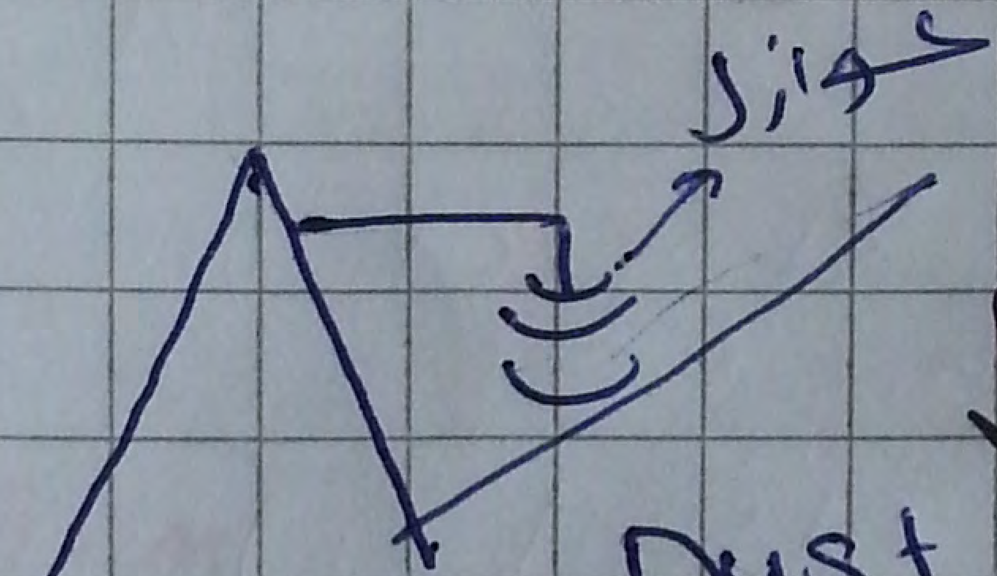
28-3-2017 lecture 9



[Conductance]

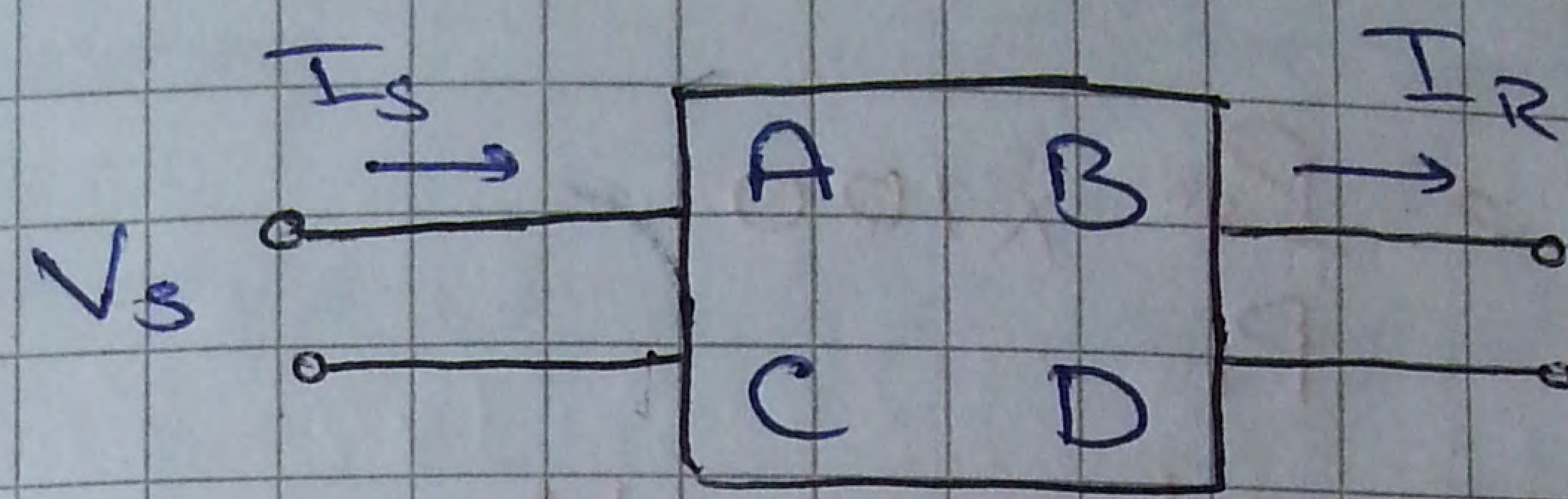
Real power

- Corona losses
  - → Rain
- leakage current at insulator
  - Dust
  - salt
  - moisture



Over head transmission line

Short	Medium	Long
< 80km	80-240km	> 240km



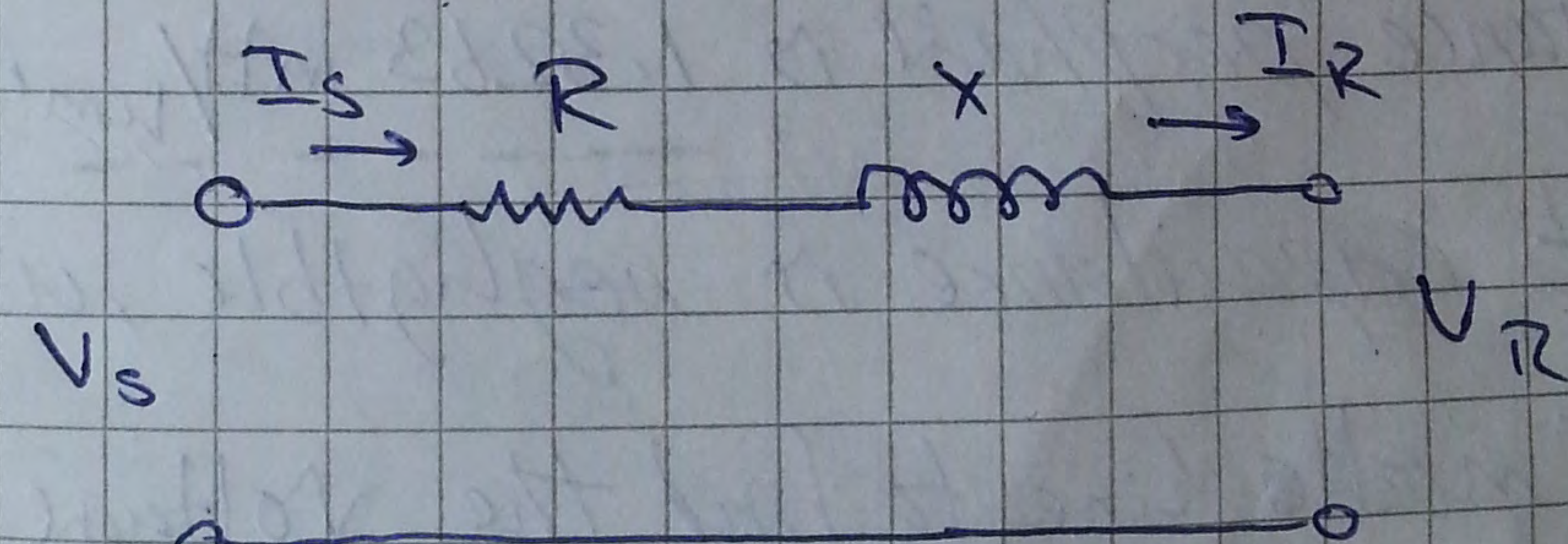
Line Parameters

$$V_s = A \times V_R + B \times I_R$$

$$I_s = C \times V_R + D \times I_R$$

$V_s \triangleq$ sending voltage
$I_s \triangleq$ sending current
$V_R \triangleq$ Receiving voltage
$I_R \triangleq$ Receiving current

Short line model



$$Z = R + jX$$

phase to nutral

$$V_s = A \times V_R + B \times I_R$$

$$V_s = I_s V_R + Z I_R$$

$$I_s = \boxed{0} V_R + \boxed{1} I_R$$

$A = 1$ $B = Z$
$C = 0$ $D = 1$

$$\eta = \frac{P_o}{P_i} \times 100$$

$$\% VR = \frac{V_{R(N\text{-}L)} - V_{R(FL)}}{V_{R(FL)}} \times 100$$

At No load $I_R = 0$

$$V_s = A V_{R(NL)} + \cancel{B \, I_R}^{\,0}$$

$$\left[V_{R(NL)} = \frac{V_s}{A} \right]$$

nominal voltage — $V/\sqrt{3}$ لأنه phase to phase — مبادئ تعاملنا في السؤال إنه phase to neutral نقسمها على

Ex :- A 220 kV, three phase T.L is 40 km the resistance per phase is 0.15 Ω/km and the inductance per phase is 1.3263 mH/km, the shunt capacitance is negligible, use the short model line to find the voltage and power at sending end and the voltage regulation and efficiency when the line is suppling a three

phase load af

power Factor ↓   زيها عندنا load V_R

a) 381 MVA at 0.8 pf lagging at 220kV → L.L

b) 381 MVA at 0.8 pf leading at 220kV   دايما معطاه العكس

$R = 0.15 \times 40 = 6\,\Omega$

$X = \omega L = 2\pi(60) * 1.3263\times10^{-3} * 40 = 20\,\Omega$

$Z = 6 + j20 = 20.881 \angle 73.3^\circ$

$V_R = \frac{220}{\sqrt{3}} = 127\ kV \angle 0^\circ$

$S_{1\phi} = V_{ph-N} * I^*$ $S_{3\phi} = \sqrt{3}\, V_{L.L} * I^*$

$S_{1\phi} = \frac{381}{3} = 127\ MVA$

$|I_R| = \frac{127\times10^6}{127\times10^3} = 1\ kA$

$F_P = \cos\theta \Rightarrow \theta = \cos^{-1}(0.8) = 36.87^\circ$

$I_R = 1\ kA \angle -36.87^\circ$

$V_s = A V_R + B I_R$

$= 1 * 127\angle 0 + 20.88\angle 73.3^\circ * 1k\angle -36.87^\circ$

$= 144.33\,kV \angle 4.93$

$|V_s|_{LL} = \sqrt{3}(144.33) = 250\,kV$

$I_s = I_R = 1\,kA \angle -36.87^\circ$

$S_{s(1\phi)} = V_{s1,} * I_s^*$

$= 144.33\angle 4.93^\circ * 1k\angle -36.87^\circ$

$= 144.33\angle 41.90^\circ$

$S_{3\phi} = 3 S_{1\phi} = 432.99\,MVA \angle 41.9^\circ$

$= \underbrace{322.8}_{P_s} + j\underbrace{288.6}_{Q_s}$

$P_R = S_R * F_P$

$= 381 \times 0.8 = 304.8 = 304.8\ MW$

$$\eta = \frac{304.8}{322.8} \times 100 = 94.40\%$$

$$\%VR = \frac{V_R(NL) - V_R(FL)}{V_R(FL)}$$

$$V_R(NL) = \frac{V_s}{A} = \frac{250}{1} = 250\ kV$$

$$\%VR = \frac{250-220}{220} \times 100 = 13.64\%$$

lecture (10)

at the last example

b) 381 MVA at 0.8 power factor leading at 220 kV

$Z = 6 + j20 \ \Omega = 20.88 \angle 73.3^\circ$

$V_R = \dfrac{220}{\sqrt{3}} = 127 \text{ kV} \angle 0$

$|I_R| = 1 \text{ kA}$ $\qquad \theta = \cos^{-1}(0.8) = 36.87^\circ$

$I_R = 1 \text{ kA} \angle 36.87^\circ$

$V_S = 1 * \underset{kV}{127} \angle 0 + \underset{\Omega}{20.88 \angle 73.3} * \underset{kA}{1} \angle 36.87$

$V_S = 121.39 \text{ kV} \angle 9.29^\circ$

$|V_{S_{L.L}}| = \sqrt{3}(121.39) = 210.26 \text{ kV}$

$I_S = I_R = 1 \text{ kA} \angle 36.87^\circ$

$S_{1\phi} = V_S I_S^*$

$= 121.39 \angle 9.29 * 1 \angle -36.87$

$S = P + jQ$

$S_{3\phi} = 3 S_{1\phi} = 364.18 \text{ MVA} \angle -27.58$

$= \underbrace{322.8}_{P} \text{ MW} - j \underbrace{168.6}_{Q} \text{ MVAr}$

$\eta = \frac{P_o}{P_i} = \frac{P_R}{P_S} \times 100$

$P_S = S \, F_p$

$= 381 * 0.8 = 304.8 \text{ MW}$

$= \frac{304.8}{322.8} \times 100 = 94.4 \%$

$V_{R(NL)} = 210.26$

$VR\% = \frac{210.26 - 220}{220} \times 100 = -4.43\%$

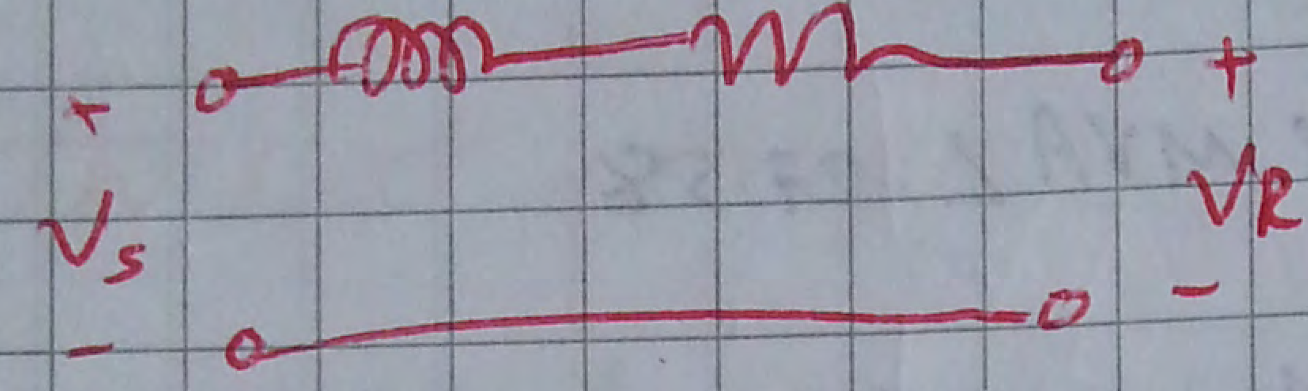
→ inductive load F_p lagging

$V_S > V_R$

→ capacitive load F_p leading

$V_S < V_R$

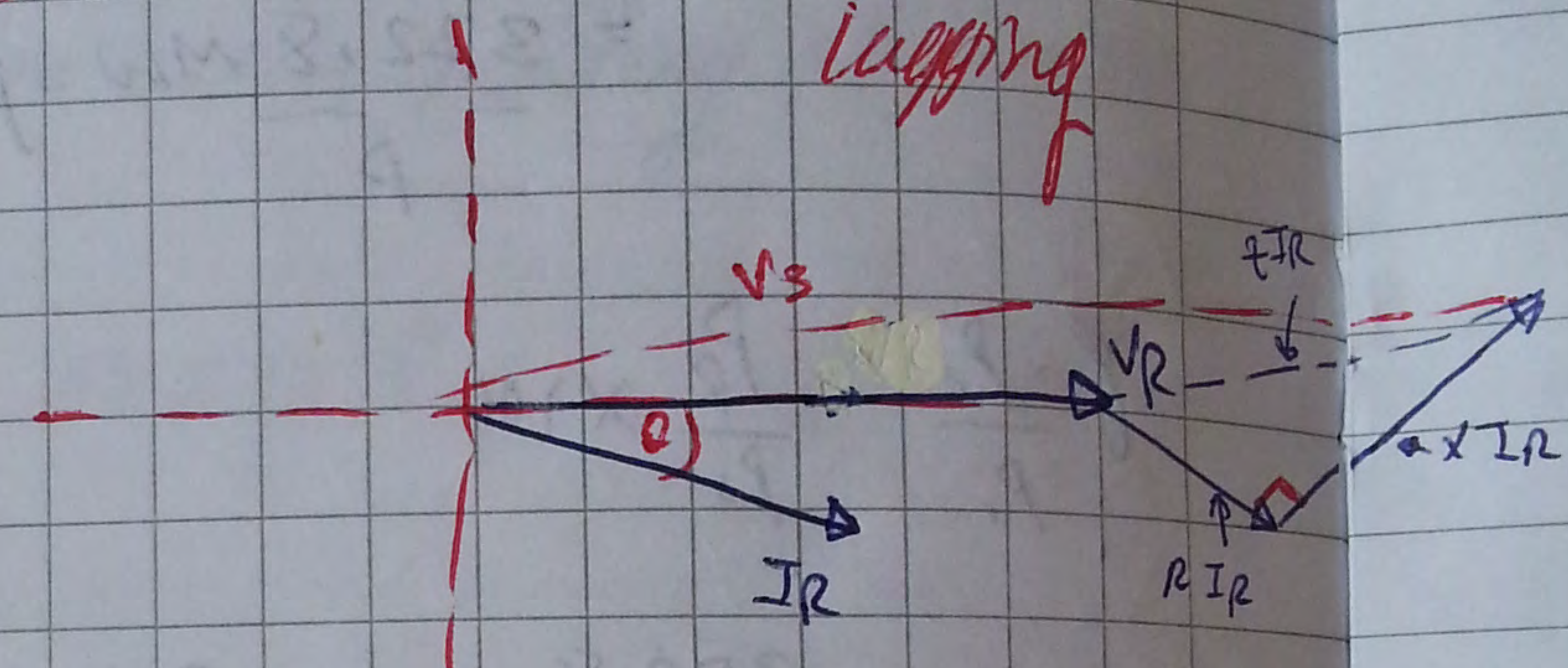
×



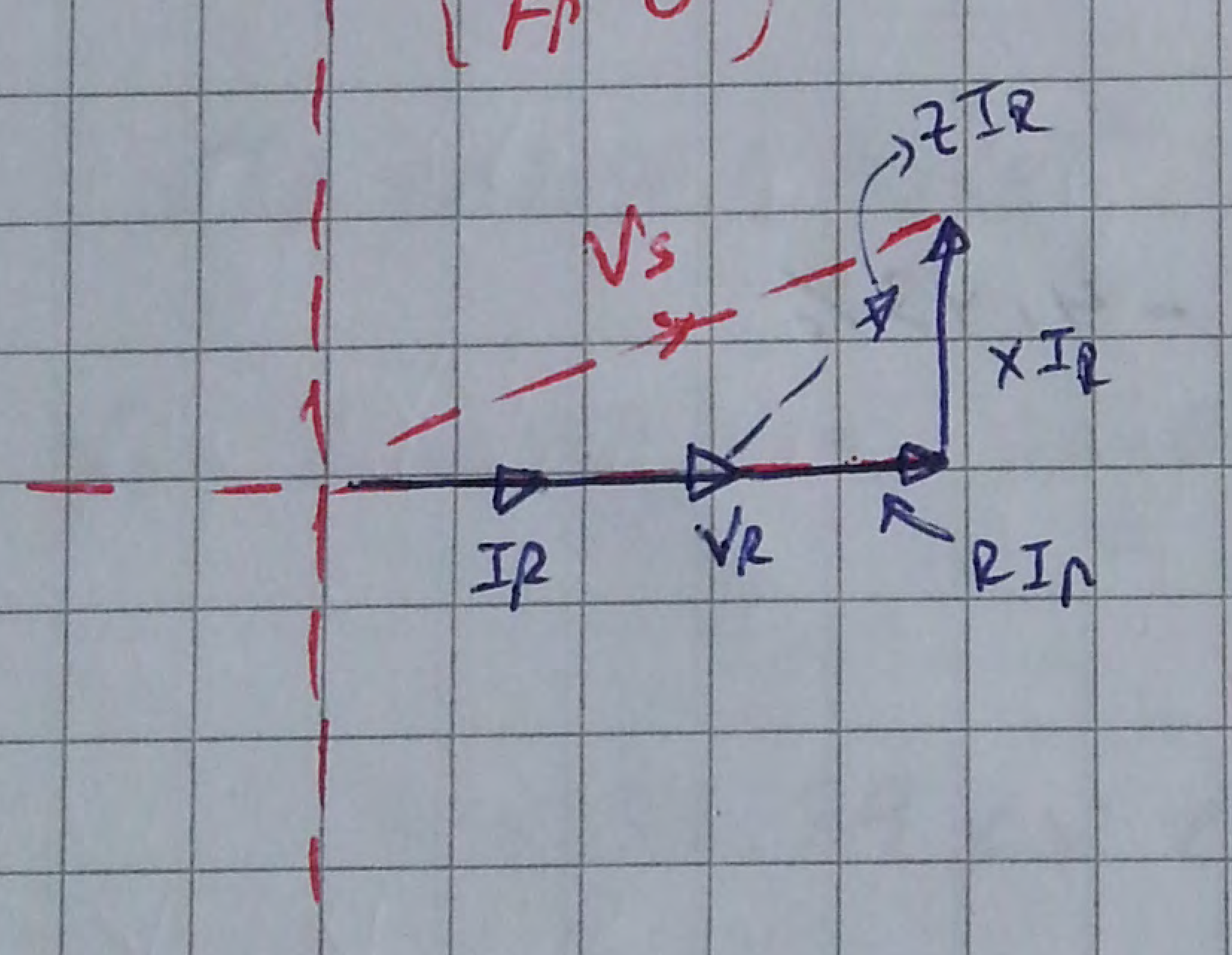
$$V_s = V_R + Z I_R$$

$$= V_R + R I_R + j X I_R$$

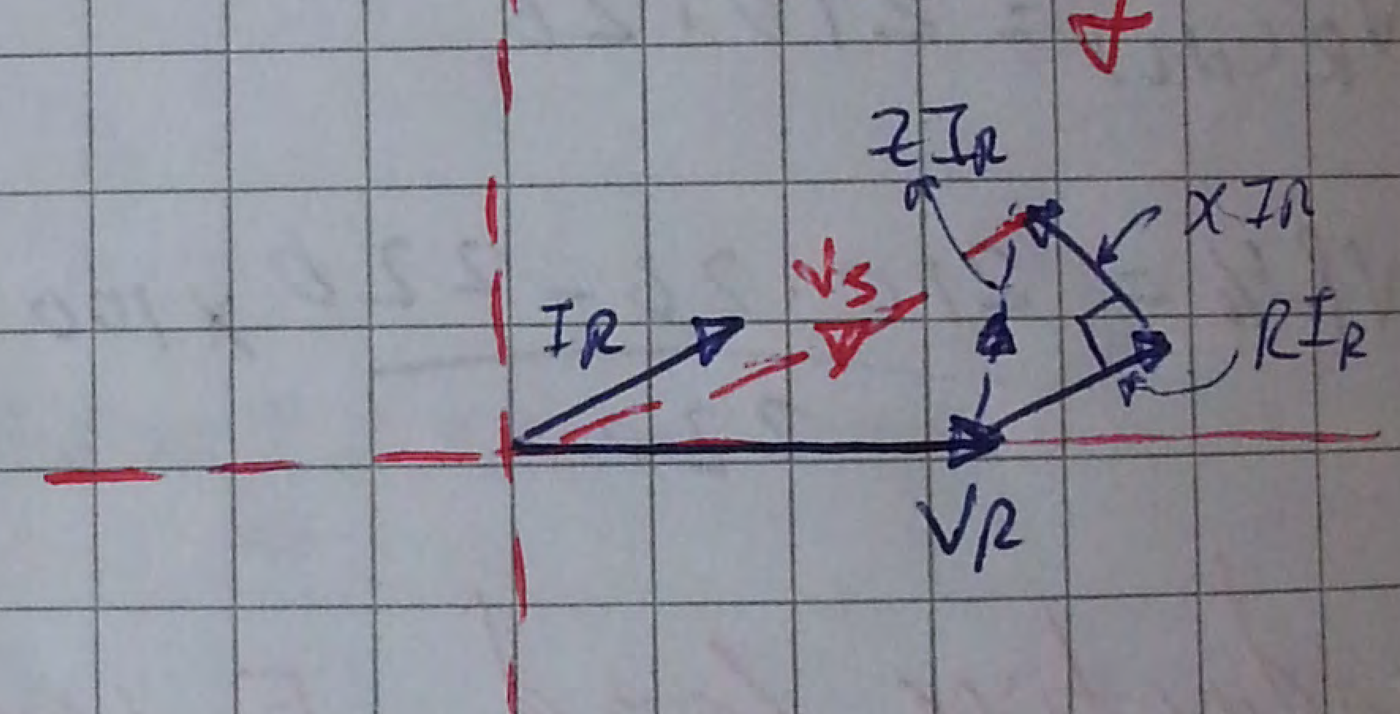
lagging



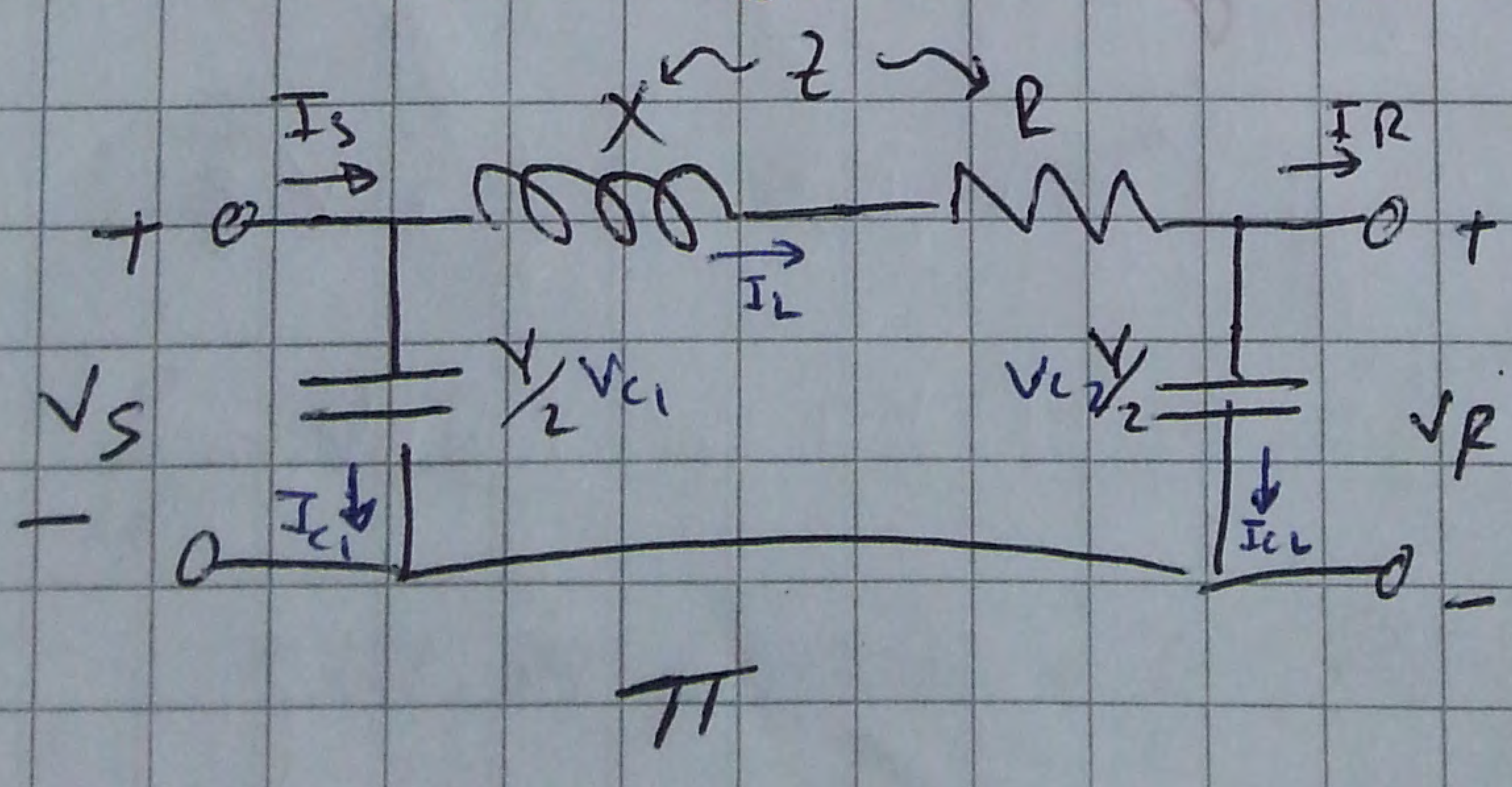
(unity FP 0) "inphase"



leading



Medium Line Mode :



$$V_S = V_R + Z I_2$$

$$= V_R + Z\,(I_{C_2} + I_R)$$

$$= V_R + Z\left(\frac{Y}{2} V_R + I_R\right)$$

$$= V_R + \frac{ZY}{2} V_R + Z I_R$$

$$= \underbrace{\left(1 + \frac{ZY}{2}\right)}_{A} V_R + \underbrace{Z}_{B} I_R$$

$$I_S = I_{C_1} + I_2$$

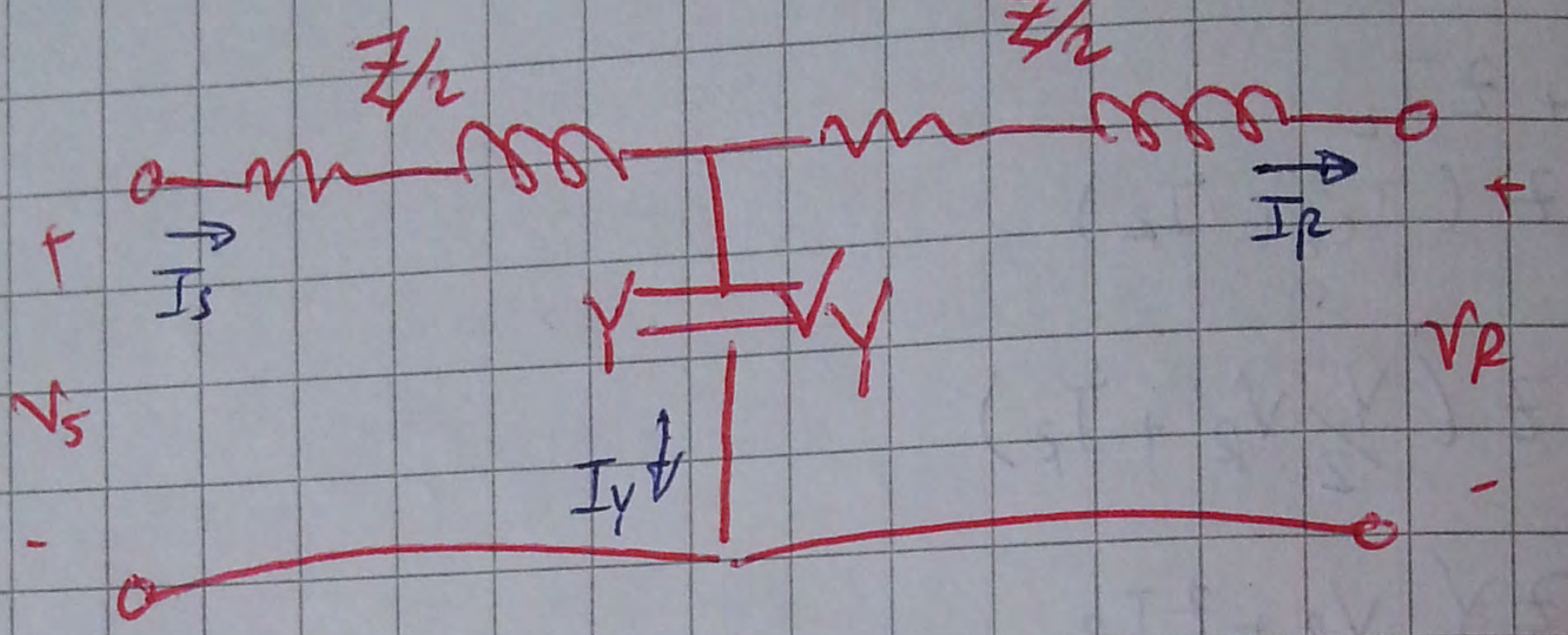
$$= \frac{Y}{2} V_S + (I_{C_2} + I_R)$$

$$= \frac{Y}{2} V_S + \frac{Y}{2} V_R + I_R$$

$$= \frac{Y}{2}\left[V_R + \frac{ZY}{2} V_R + Z I_R\right] + \frac{Y}{2} V_R + I_R$$

$$= Y V_R + \frac{Z Y^2 V_R}{4} + \frac{ZY}{2} I_R + I_R$$

$$I_S = \underbrace{Y\left(1 + \frac{ZY}{4}\right)}_{C} V_R + \underbrace{\left(1 + \frac{ZY}{2}\right)}_{D} I_R$$



T

$$I_s = I_R + I_Y$$

$$= I_R + Y V_Y$$

$$= I_R + Y\left[V_R + \frac{Z}{2} I_R\right]$$

$$= Y V_R + I_R + \frac{ZY}{2} I_R$$

$$I_s = \underbrace{Y}_{C} V_R + \underbrace{\left(1 + \frac{ZY}{2}\right)}_{D} I_R$$

$$V_s = V_Y = \frac{Z}{2} I_s$$

$$= V_R + \frac{Z}{2} I_R + \frac{Z}{2}\left[Y V_R + I_R + \frac{ZY}{2} I_R\right]$$

$$= V_R + \frac{Z}{2} V_R + \frac{Z}{2} I_R + \frac{Z^2 Y}{4} I_R$$

$$= \underbrace{\left(1 + \frac{ZY}{2}\right)}_{A} V_R + \underbrace{Z\left(1 + \frac{ZY}{4}\right)}_{B} I_R$$

Ex :-

a) Determine the capacitance to nutral in μf/mi

of the capacitive reactance to nutral in Ω.mi

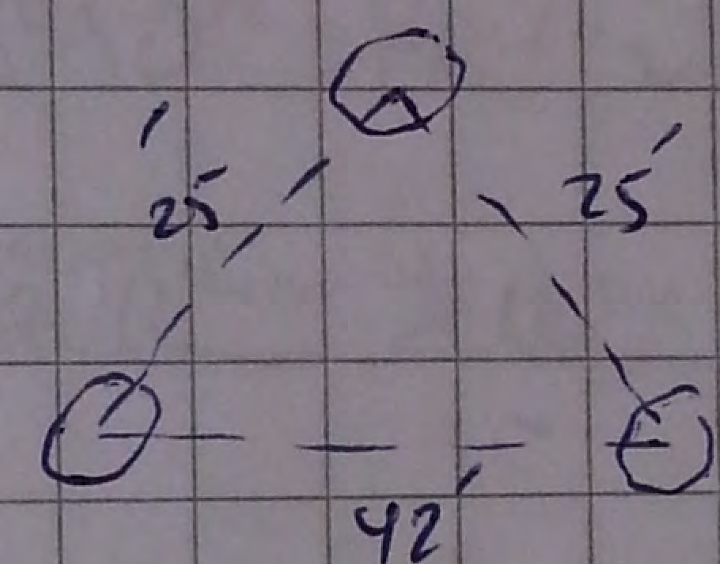
b) If the line is 150 mile long, find the capacitance

to nutral and the capacitive reactance of the line

From the table $r = \frac{D}{2} = \frac{0.879}{2} =$

$r = 0.4395$ in

$r = \frac{0.4395}{12} = 0.036625$ ft



ACSR
Osprey

a) $C = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right)} = \frac{2\pi\epsilon_0}{\ln\left(\frac{\sqrt[3]{25 * 25 * 42}}{0.036625}\right)} = 8.3\,pF/m$

$C = 1609 \times 8.3\,p = 0.0134\,\mu F$/mile

$X_c = \frac{1}{wc} = \frac{1}{2\pi fc} = 198.5\,k\Omega$.mile

b) $C = 2.01\,\mu F$

$X_c = 1.319\,k\Omega$

lecture (11)

تابع المثال السابق

(٣) نجد قيمة X_c باعتبارها من الجدول

$$X_c = X'_a + X'_d$$

$X_a = 0.0981 \ M\Omega.mile$ ← من الجدول

X_d = value at GMD = 29.72

وبما أن هذه القيمة لا توجد فهنالك حلين

① باستخدام Interpolation

② بتطبيق المعادلة

$$X_d = 0.06831 \log(d)$$

$$= 0.6831 \log(29.72)$$

$$= 0.1006 \ M\Omega.mile$$

$$\frac{30-29}{0.1009-0.099} = \frac{29.72-29}{x-0.0999} \Rightarrow x = 0.101 \simeq 0.01006$$

$X_c = 0.981 + 0.1006 = 198.7\,k\Omega.\text{mile}$

Find the total charge current and the total charge in mega volt ampers

$I_{ch} = JWCV$ capacitance to nutral; phase to nutral

assume 3ϕ at 220kV line to line

$V_{LL} = \sqrt{3}\, V_{ph\,n}$

$|I_{ch}| = 2\pi(60)(2.01\mu) \times \frac{220k}{\sqrt{3}}$

$|I_{ch}| = 96.185\,A$

$S = P + jQ$

$Q_{3\phi} = \sqrt{3}\, V_{LL} \boxed{I \sin\theta}$ $\rightarrow I_{ch}$

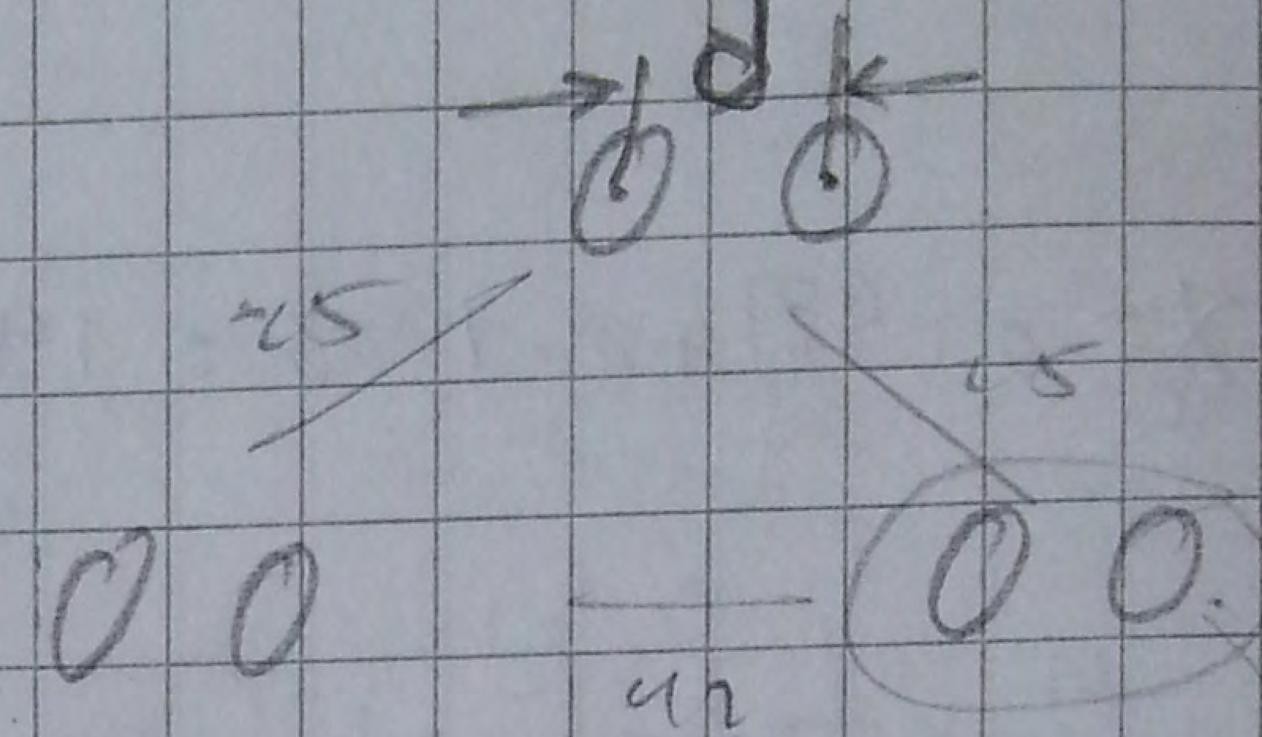
$= \sqrt{3}\,(220k)(96.185) = 36.03\,MVA_r$

$Q_{1\phi} = V_{ph\text{-}N}\, I \sin\theta$

$= \frac{220}{\sqrt{3}}(96.185)$

$\Rightarrow Q_{3\phi} = 3\phi_{1\phi}$

For



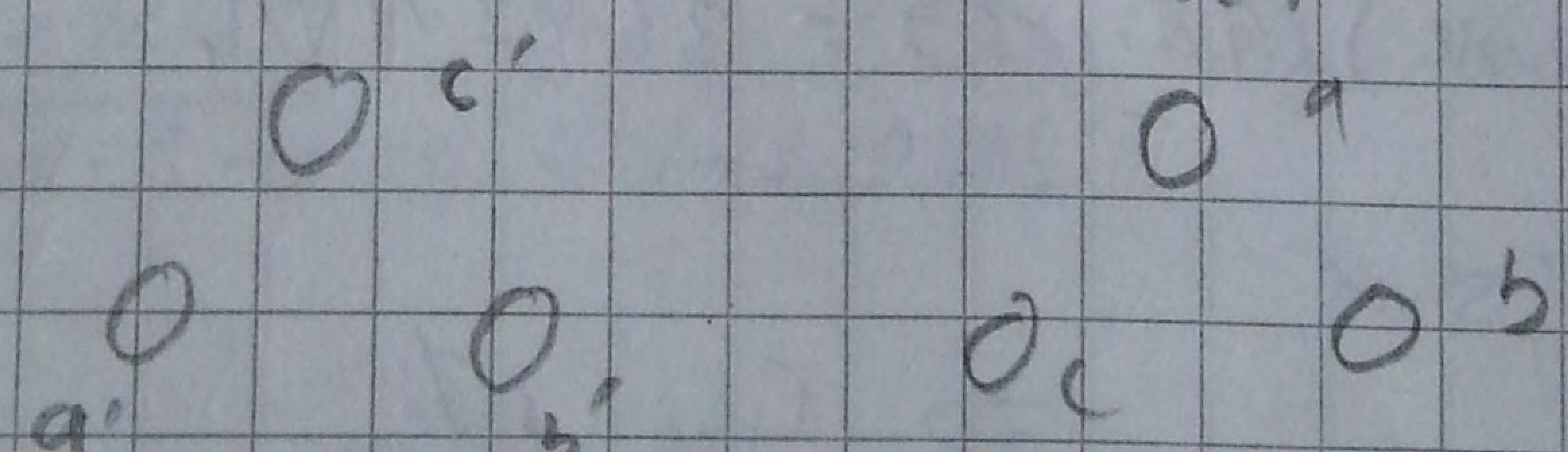
From table

R_{ac} at $50°C$ 60Hz $= 0.1843\ \Omega/\text{mile}$

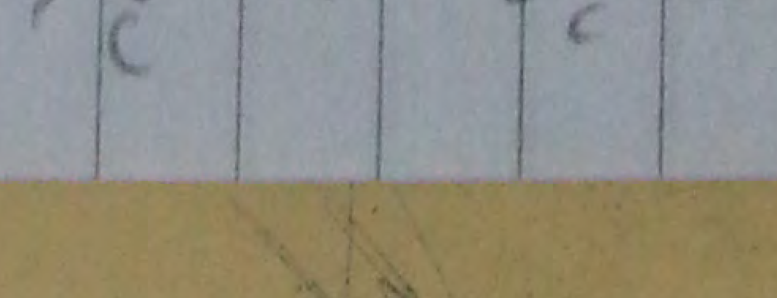
$$C = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{GMR_c}\right)}$$

$GMR_c =$	r	1	عدد الـ cond
	$\sqrt{r \times d}$	2	يرمز للسؤال 2
	$\sqrt[2]{rd^2}$	3	

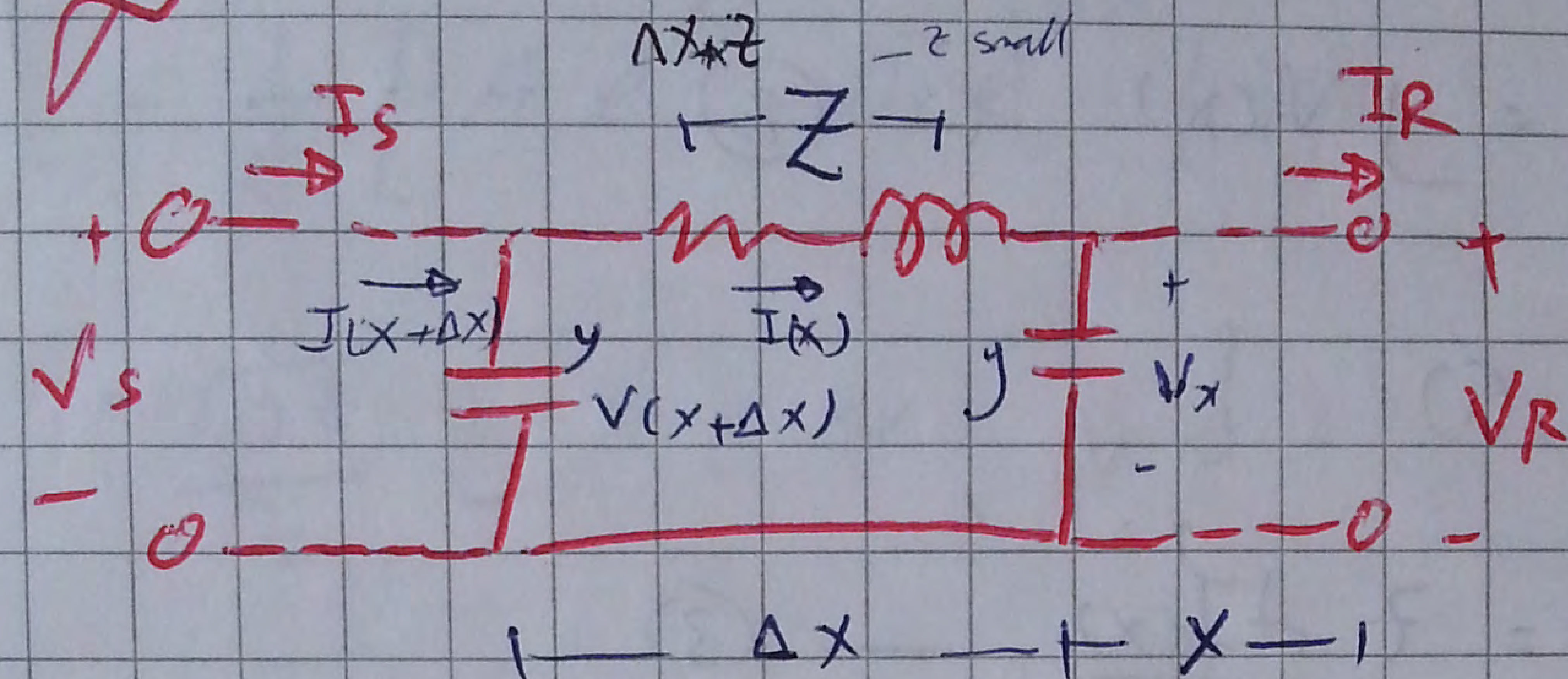
capacitance بر ال double cct في ال — ملاحظة مهمة



الترتيب يختلف مش زي ال inductance



Long Line Model :-



z small

Z = Series impedence / unit length

y = Shunt admittance

$$V(x+\Delta x) = V(x) + \Delta x\, z\, I(x)$$

$$z\, I(x) = \frac{V(x+\Delta x) - V(x)}{\Delta x}$$

$$\Delta x \rightarrow 0$$

$$\frac{dV(x)}{dx} = z\, I(x) \quad — ①$$

$$I(x-\Delta x) = I(x) + \Delta x * y * V(x+\Delta x)$$

$$\frac{I(x+\Delta x) - I(x)}{\Delta x} = y\, V(x+\Delta x)$$

$\Delta x \rightarrow 0$

$$\frac{dI(x)}{dx} = y\,V(x) \quad \text{—— (2)}$$

diff eq (1)

$$\frac{d^2 V(x)}{dx^2} = z\,\frac{dI(x)}{dx} \quad \text{—— (3)}$$

Sub (3) in (2)

$$\frac{d^2 V(x)}{dx^2} = \underbrace{z\,y}_{\gamma^2}\,V(x)$$

$$(1) \text{ —— } \frac{d^2 V(x)}{dx^2} - \gamma^2 V(x) = 0$$

diff equation in order 1

$$V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x}$$

$\gamma = \sqrt{zy}$ ≡ propagation Constant

$\gamma = \alpha + j\beta$

α → attenuation constant

β → phase constant

$$I(x) = \frac{1}{Z} \frac{dV(x)}{dx}$$

$$= \frac{1}{Z} \left[A_1 e^{\gamma x} - A_2 e^{-\gamma x} \right] \gamma$$

$$= \frac{\sqrt{yz}}{z} \left[\quad " \quad \right]$$

$$= \sqrt{\frac{y}{z}} \left[\quad " \quad \right]$$

$$Z_c = \sqrt{\frac{z}{y}}$$ characteristic impedence

$$I(x) = \frac{1}{Z_c} \left[A_1 e^{\gamma x} - A_2 e^{-\gamma x} \right] \quad — ②$$

To find A_1 and A_2

at $x = 0 \implies V(x) = V_R \quad , \quad I(x) = I_R$

$$V_R = A_1 + A_2$$

$$I_R = \frac{1}{Z_c} (A_1 - A_2)$$

$$\implies A_1 = \frac{V_R + Z_c I_R}{2} \quad , \quad A_2 = \frac{V_R - Z_c I_R}{2}$$

Long Model more accurate than midim model

[illegible] midim = [illegible] long = [illegible]

$$V(x) = \left(\frac{V_R + Z_c I_R}{2}\right) e^{\gamma x} + \left(\frac{V_R - Z_c I_R}{2}\right) e^{-\gamma x}$$

$$I(x) = \frac{1}{Z_c}\left[\left(\frac{V_R + Z_c I_R}{2}\right) e^{\gamma x} - \left(\frac{V_R - Z_c I_R}{2}\right) e^{-\gamma x}\right]$$

$$V(x) = \underbrace{\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)}_{\cosh} V_R + Z_c \underbrace{\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)}_{\sinh} I_R$$

$$I(x) = \frac{1}{Z_c}\underbrace{\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right)}_{\sinh} V_R + \underbrace{\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)}_{\cosh} I_R$$

Line length $= L = x$

$V(l) = V_s$, $I(l) = I_s$

$$V_s = \underbrace{\cosh(\gamma l)}_{A} V_R + \underbrace{Z_c \sinh(\gamma l)}_{B} I_R$$

$$I_s = \underbrace{\frac{1}{Z_c}\sinh(\gamma l)}_{C} V_R + \underbrace{\cosh(\gamma l)}_{D} I_R$$

$(AD - BC = 1)$

$$\bar{Z} = Z_c \sinh(\gamma l)$$

$$= \frac{\sqrt{z}}{\sqrt{y}} \times \frac{\sqrt{z}}{\sqrt{z}} \times \frac{l}{l} \sinh(\gamma l)$$

$$= \frac{\overset{\sim Z}{zl}}{\gamma l} \sinh(\gamma l)$$

$$\bar{Z} = \frac{Z}{\gamma l} \sinh(\gamma l)$$

$$1 + \frac{Z\bar{Y}}{2} = \cosh(\gamma l)$$

$$1 + \frac{\bar{Y} Z_c \sinh(\gamma l)}{2} = \cosh(\gamma l)$$

$$\frac{\bar{Y}}{2} = \frac{\cosh(\gamma l) - 1}{Z_c \sinh(\gamma l)}$$

$$= \frac{1}{Z_c} \tanh\left(\frac{\gamma l}{2}\right)$$

$$\boxed{\frac{\bar{Y}}{2} = \frac{Y}{2} \frac{\tanh(\gamma l/2)}{(\gamma l/2)}}$$

$$\frac{2\pi}{\frac{\omega}{v}} = \frac{2\pi v}{2\pi f} =$$

lecture (13

Voltage and current waves :-

velocity of propagation $v = \frac{\omega}{\beta}$

wave length $\lambda = \frac{2\pi}{\beta} = v/f$

Ex :- A single cct 60HZ T.L, is 370km (230mile) long. The conductors are Rook with flat horizontal, spacing 7.25m (23.8ft) between conductors, the load on the line is 125 MW at 215 kV with 100% PF Find the voltage, current and power at sending end and % V.R of the line, Also determine the wave length and velocity of propagation of the line

z =

γ =

z

Fr

zero

$z = \Omega / \text{unit length}$ $\qquad Z = \Omega$

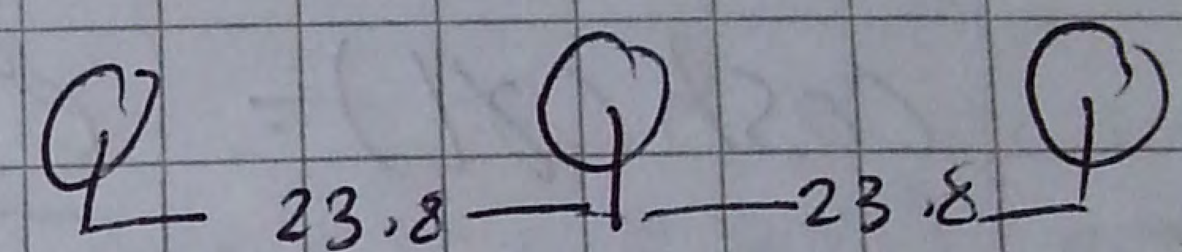
$\rightarrow r + jX_L$

$$\gamma = \alpha + j\beta = \sqrt{zy} \implies \gamma l = l\sqrt{zy}$$

$$z = r + jX_L$$

From table r (AC at $50^\circ C$)

$$r = 0.1603 \ \Omega/\text{mile}$$



$\rightarrow$ For GMD

$$X_L = X_a + X_d = 0.415 + 0.4127 = 0.8277 \ \Omega/\text{mile}$$

$$GMD = \sqrt[3]{23.8 \times 23.8 \times (23.8 \times 2)} = 30 \text{ ft}$$

$$Z = 0.1603 + j0.8277 = 0.8431 \angle 79.04^\circ \ \Omega/\text{mile}$$

Zero [illegible]

$$y = g + jb \implies y = jb = j\frac{1}{X_c} = j\frac{1}{X'_a + X'_d}$$

$$y = j\frac{1}{0.0950 + 0.1009}$$

X'_a From table $= 0.0950$ $M\Omega \cdot mi$

$X'_d = 0.1009$ $M\Omega \cdot$mile

$$y = 5.105 \times 10^{-6} \angle 90^\circ \ S/\text{mile}$$

تحت الجذر الزوايا تنجمع وتنقسم على $\underline{2}$

$$\gamma l = l\sqrt{zy} = 230\sqrt{0.8431 \times 5.105 \times 10^{-6}} \angle \frac{79.04+90}{2}$$

$$= 0.4772 \angle 84.52^\circ = 0.456 + j0.475$$

$$\gamma l = \underbrace{0.0456}_{\alpha l} + j\underbrace{0.475}_{\beta l = rad}$$

rad $\longrightarrow$ degree

$$\frac{0.475 \times 180}{\pi} = 27.22^\circ$$

$$\cosh(\gamma l) = \frac{e^{\gamma l} + e^{-\gamma l}}{2}$$

$$= \frac{1}{2} e^{\alpha l} \angle \beta l + \frac{1}{2} e^{-\alpha l} \angle -\beta l$$

$$= \frac{1}{2} e^{0.0456} \angle 27.22^\circ + \frac{1}{2} e^{-0.0456} \angle -27.22$$

$$= 0.8902 + j0.0209 = 0.8904 \angle 1.34^\circ$$

$$\sinh(\gamma l) = \frac{e^{\gamma l} - e^{-\gamma l}}{2}$$

$$\sinh(\gamma l) = \frac{1}{2} e^{\alpha l} \angle \beta l - \frac{1}{2} e^{-\alpha l} \angle -\beta l$$

$$= 0.0406 + j0.4579 = 0.4597 \angle 84.93^\circ$$

$$V_R = \frac{215}{\sqrt{3}} \angle 0 = 124.13 \angle 0^\circ \ kV$$

$$P_{3\phi} = \sqrt{3}\, I V_{L.L} \cdot p.f$$

$$I = \frac{125 \times 10^6}{\sqrt{3} \times 215 \times 10^3 \times 1} = 335.7 A \angle 0^\circ$$

$$Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{0.8431}{5.105 \times 10^{-6}}} \angle \frac{79.04 - 90}{2}$$

$$Z_c = 406.4 \angle -5.46 \ \Omega$$

$$V_s = \underbrace{(0.8904 \angle 1.34^\circ)}_{\cosh(\gamma l)} \underbrace{\left[124.13 \angle 0^\circ \times 10^3\right]}_{V_R} + \underbrace{(406.4 \angle -5.84)}_{Z_c} \underbrace{\left[0.4597 \angle 84.93\right]}_{\sinh(\gamma l)} \underbrace{\left[335.7 \angle 0^\circ\right]}_{I_R}$$

$$V_s = 137.86 \angle 27.69 \text{ kV}$$

$$|V_s|_{L.L} = 137.86 \sqrt{3} = 238.8 \text{ kV}$$

$$I_s = \frac{1}{406.4 \angle -5.84^\circ} * 0.4597 \angle 84.93^\circ * 124.13 \angle 0^\circ + 0.8904 \angle 1.34^\circ * 0.3357 \angle 0$$

$$= 332.31 \angle 26.33 A$$

$$P_s = \sqrt{3} V_s I_s \, Pf_s$$

$$Pf_s = \cos(27.77 - 26.33) = 0.9997 \simeq 1.0$$

$$P_s = \sqrt{3} \underbrace{(238.8)}_{kV} \underbrace{(0.3323)}_{kA} (1) = 137.14 \text{ MW}$$

$$\% VR = \frac{V_{R(NL)} - V_{R(FL)}}{V_{R(FL)}} \times 100$$

$$V_{R(NL)} = \frac{V_S}{A} = \frac{137.86}{0.8904} = 154.83 \text{ kV}$$

$$\% VR = \frac{154.83 - 124.13}{124.13} \times 100 = 24.7 \ \%$$

$$\beta = \frac{0.475}{230} = 0.002065 \text{ rad/mil}$$

$$v = \frac{\omega}{\beta} = \frac{2\pi(60)}{0.002065} = 182580 \text{ mi/sec}$$

$$\lambda = v/f = \frac{182580}{60} = 3043 \text{ mile}$$

Ex: Find the equivalent π circuit for the line described in previous example and compare it with the normal π circuit

$$\bar{Z} = Z_c \sinh(\gamma l) = (406.41 \angle -5.48)(0.4597 \angle 84.93^\circ)$$

$$\bar{Z} = 186.82 \angle 79.45^\circ \ \Omega$$

$$\frac{\bar{Y}}{2} = \frac{1}{Z_c}\tanh\left(\frac{\gamma l}{2}\right) = \frac{1}{Z_c}\cdot\frac{\cosh(\gamma l)-1}{\sinh(\gamma l)}$$

$$Z_c \sinh(\gamma l) = \bar{Z}$$

$$= \frac{(0.8902 + j0.0209) - 1}{186.82\angle 79.45^\circ} = 0.000599\angle 89.82^\circ \ \mho$$

$$Z = zl = 0.8431\angle 79.04 * 230 = 193.9\angle 79.04^\circ$$

$$\frac{Y}{2} = \frac{y\times l}{2} = \frac{5.105\times 10^{-6}\angle 90 \times 230}{2}$$

$$= 0.000587\angle 90 \ \mho$$

$Z > \bar{Z}$ by 3.8%

$\frac{Y}{2} < \frac{\bar{Y}}{2}$ by 2%

lecture (14)

$$V(x) = \cosh(\gamma x) V_R + Z_c \sinh(\gamma x) I_R$$

$$I(x) = \frac{1}{Z_c} \sinh(\gamma x) V_R + \cosh(\gamma x) I_R$$

$$v = \frac{\omega}{\beta} \quad , \quad \lambda = v/f$$

Lossless Line :

$$r = 0 \quad , \quad g = 0$$

$$Z = r + j\omega L \quad , \quad y = g + j\omega c$$

$\gamma = \alpha + j\beta$ with $r=0$ and $g=0$ $\Longrightarrow$ $\boxed{\gamma = j\beta}$

$$\gamma = \sqrt{zy} = \sqrt{j\omega L + j\omega c} = j\omega\sqrt{LC}$$

$$\boxed{\beta = \omega\sqrt{LC}}$$

$\boxed{Z_c = \sqrt{\frac{Z}{y}} = \sqrt{\frac{L}{C}}}$ $\longrightarrow$ in loss Line ≡ pure resistance

$$\boxed{v = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}}$$

$$\boxed{\lambda = \frac{v}{f} = \frac{1}{f\sqrt{LC}}}$$

Neglecting Internal flux :-

$$GMR_L = GMR_C$$

$$L = \underbrace{2\times 10^{-7}}_{=\mu_0} \ln\left(\frac{GMD}{GMR}\right)$$

r

r' [illegible]

[illegible] (int)

$$C = 2\pi\epsilon_0 \Big/ \ln\left(\frac{GMD}{GMR}\right)$$

$$v = \frac{1}{\sqrt{LC}} \simeq \frac{1}{\sqrt{\mu_0\epsilon_0}} = 3\times 10^{8}\ \text{m/s}$$ speed of light

$$\lambda = \frac{1}{f\sqrt{LC}} = \frac{1}{f\sqrt{\mu_0\epsilon_0}} = 5000\ \text{km}$$

$f \to$ 60 Hz

$$Z_c = \sqrt{\frac{L}{C}} = \frac{1}{2\pi}\sqrt{\frac{\mu_0}{\epsilon_0}}\ \ln\left(\frac{GMD}{GMR_c}\right)$$

$$\simeq 60 \ln\left(\frac{GMD}{GMR_c}\right)$$

$$\cosh(\gamma x) = \cosh(j\beta x) = \cos(\beta x)$$
$$\sinh(\gamma x) = \sinh(j\beta x) = j\sin(\beta x)$$

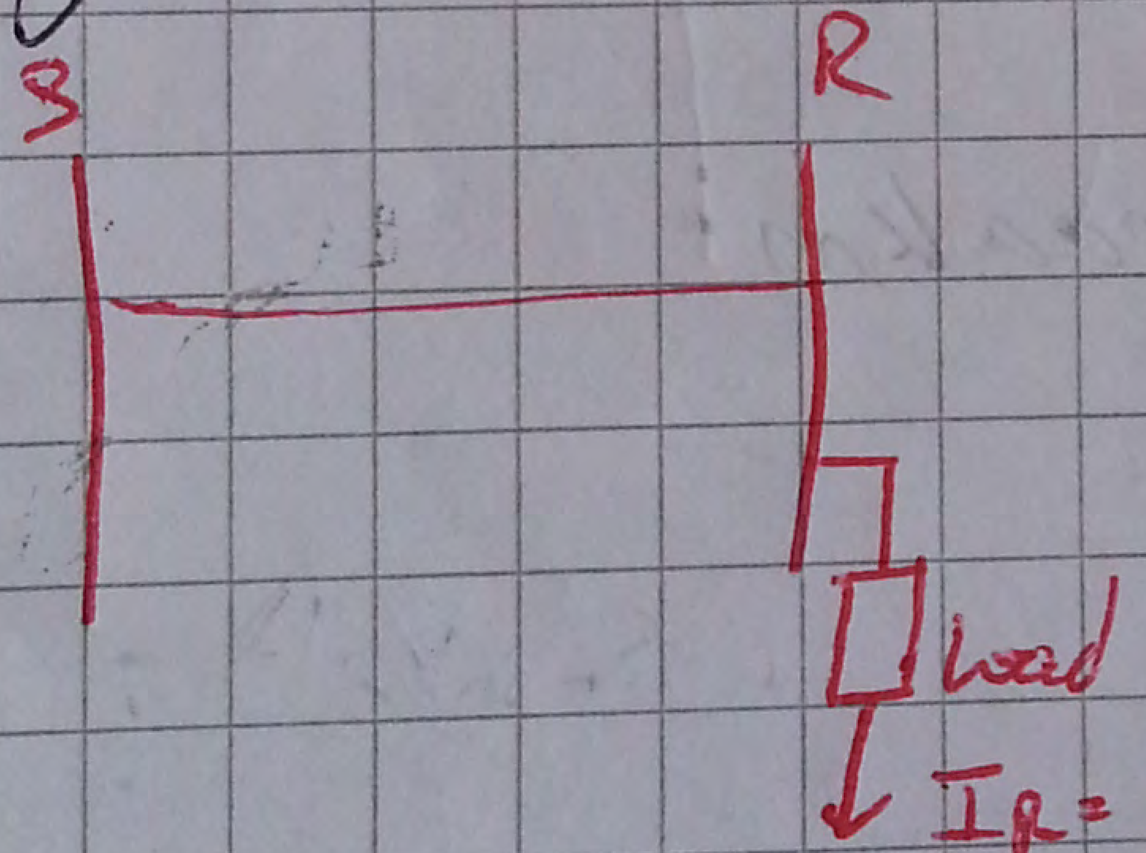
$Z_c \equiv$ charct impedance $\equiv$ Surge impedance

$$V(x) = \cos(\beta x) V_R + j Z_c \sin(\beta x) I_R$$

$$I(x) = j \frac{1}{Z_c} \sin(\beta x) V_R + \cos(\beta x) I_R$$

For typical T.L Z_c Varies from 400 Ω for 69 kV – 250 Ω for double cct 765 kV

Surge Impedance Loading :



$$I_R = \frac{V_R}{Z_c}$$

for 3ϕ

ph-N

$$SIL = 3 V_R I_R^*$$

$$= \frac{3 V_R^2}{Z_c}$$

$$SIL = \frac{3\left(\frac{V_{R_{L.L}}}{\sqrt{3}}\right)^2}{Z_c} = \frac{V_{R_{L.L}}^2}{Z_c} \quad MW$$

in The example of Last lecture

using Lossline assumption

$l = 230$ mi , $z = 0.1603 + j0.8277$

$y = 5.105 \times 10^{-6}$ S/mi

$V_R = 124.13 \angle 0$ kV

$I_R = 335.7 \angle 0$ A

$z = jX_L \Rightarrow X_L = 0.8277 \Rightarrow L = \frac{0.8277}{2\pi f}$

$L = 2.1955$ mH/mile

$\frac{1}{X_c} = 5.105 \times 10^{-6} = \omega C \Rightarrow C = 1.35 \times 10^{-8}$ F/mile

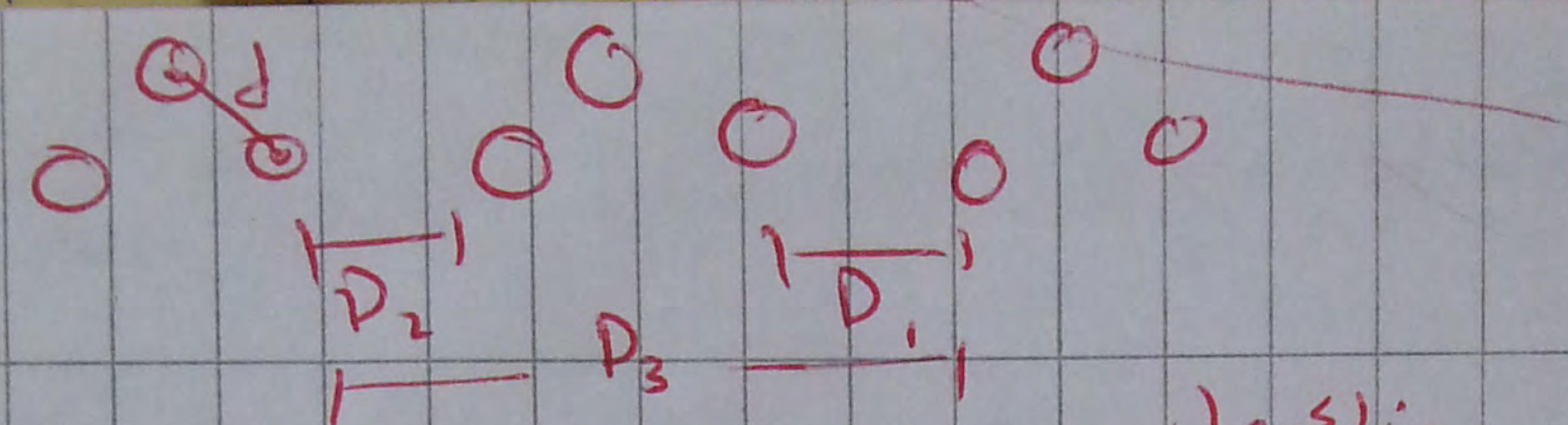
$\gamma l = l\sqrt{zc} = l\,j\omega\sqrt{LC} = l\,j\,2.03 \times 10^{-3}$

$\beta l = 2.03 \times 10^{-3}$ rad/mile $\times 230 = \beta l = 4.669 \times 10^{-4}$ rad/mile

$Z_c = \sqrt{\frac{L}{C}} = 403.27\ \Omega$

$V(x) = 124.12 e^{j3}$

lecture (15)

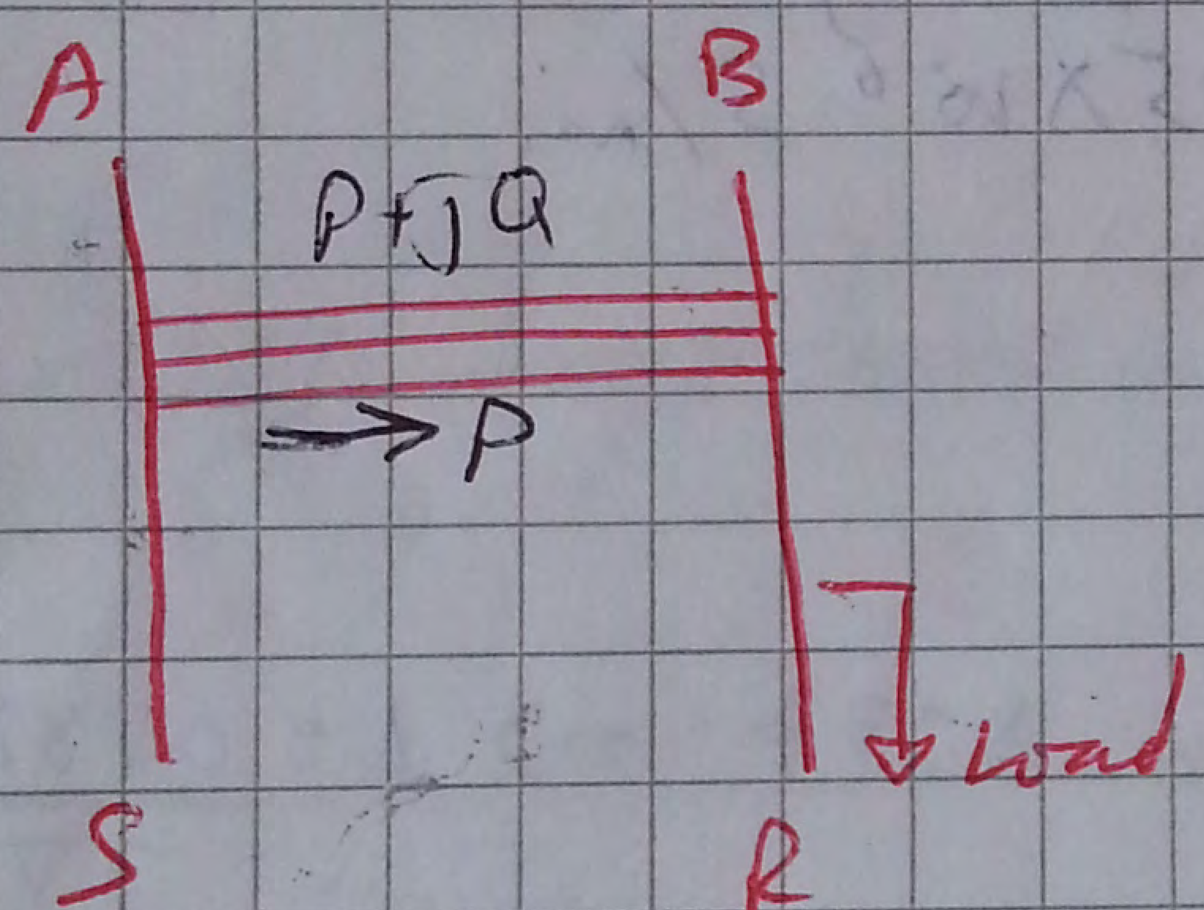


من الجدول

$$GMD = \sqrt[3]{D_1 D_2 D_3} \qquad GMR = \sqrt{GMR * d^2}$$

$$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR}\right)$$

Complex power flow Through T.L :-



$$S = P + jQ$$

$$\left.\begin{aligned} S &= A\angle\theta \\ P &= A\cos\theta \\ Q &= A\sin\theta \end{aligned}\right\} \quad (1)$$

$$V_S = A V_R + B I_R$$

$$A = |A|\angle\theta_A \quad , \quad B = |B|\angle\theta_B$$

$$V_R = |V_R|\angle 0^\circ \qquad V_S = |V_S|\angle\delta$$

$$I_R = \frac{|V_S|\angle\delta - (|A|\angle\theta_A)(|V_R|\angle 0^\circ)}{|B|\angle\theta_B}$$

$$I_R = \frac{|V_S|}{|B|} \angle \delta - \theta_B - \frac{|A||V_R|}{|B|} \angle \theta_A - \theta_B$$

$$S_{R(3\phi)} = P_{R(3\phi)} + j\,Q_{R(3\phi)} = 3\, V_{R_{ph-n}} I^*$$

$$S_{R(3\phi)} = 3\frac{|V_{R_{ph.n}}||V_{S_{ph.n}}|}{|B|} \angle \theta_B - \delta - \frac{3|V_{R_{ph.n}}||A||V_{R_{ph.n}}|}{|B|} \angle \theta_B - \theta_A$$

$$V_{ph-N} = V_{LL} / \sqrt{3}$$

$$S_{R(3\phi)} = \frac{|V_{R(L.L)}||V_{S(L.L)}|}{|B|} \angle \theta_B - \delta - \frac{|A||V_{R(L.L)}|^2}{|B|} \angle \theta_B - \theta_A$$

using 1

$$P_{R(3\phi)} = \frac{|V_{R(L.L)}||V_{S(L.L)}|}{|B|} \cos(\theta_B - \delta) - \frac{|A||V_{R(L.L)}|^2}{|B|} \cos(\theta_B - \theta_A)$$

$$Q_{R(3\phi)} = \quad '' \quad \sin(\theta_B - \delta) - \quad '' \quad \sin(\theta_B - \theta_A)$$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

$$V_R = D V_S - B I_S$$

$$I_R = -C V_S + A I_S$$

$[A = D]$

$$V_R = D V_S - B I_S \Longrightarrow I_S = \frac{A V_S - V_R}{B}$$

Lossless Line

$B = J Z_c \sin(\beta l)$ $\quad\quad$ $A = \cos(\beta l)$

لما أن (B) complex only

$\theta_B = 90^\circ$ نلا

بما أن (A) Real only

$\theta_A = 0^\circ$ نلا

$$\cos(\theta_B - \theta_A) = \cos(90) = 0$$

$$\cos(\theta_B - \delta) = \sin(\delta)$$

power Transmission Capability :-

1) Thermal limit

2) Voltage limit

3) stability Limit

$S_{Thermal}$ = Thermal loading Limit = $3 V_{Rated} I_{Thermal}$

$$P.U = \frac{Actual}{Base} \quad \text{power. unit}$$

$$V_{R(p.u)} = \frac{V_R}{V_{rated}} \quad , \quad V_{s(p.u)} = \frac{V_s}{V_{base}}$$

$$P_{3\phi} = \left(\frac{|V_{R(p.u)}|}{|V_{rated}|} \right) \left(\frac{|V_{s(p.u)}|}{|V_{rated}|} \right) \left(\frac{V_{rated}^2}{Z_c \sin(\beta l)} \sin\delta \right)$$

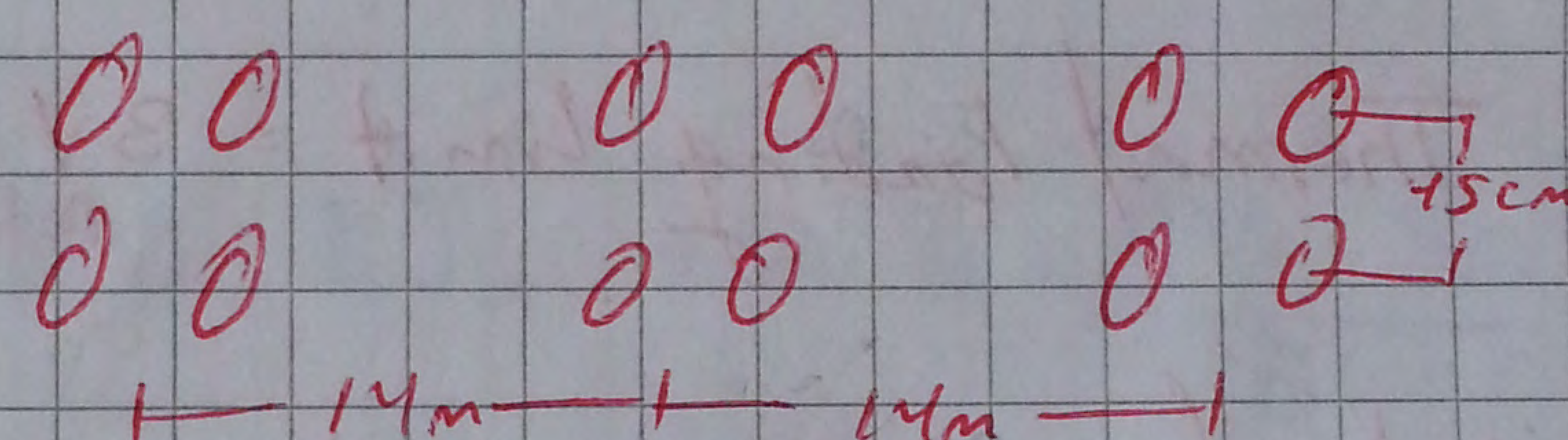
$$= |V_{R(p.u)}| * |V_{s(p.u)}| * SIL \quad \#$$

$$P_{3\phi} = \frac{|V_s|_{p.u} * |V_R|_{p.u} * SIL}{\sin\left(\frac{2\pi l}{\lambda}\right)} \sin\delta$$

lecture (16

Ex (prob. 5.8 Saadat)

3ϕ, 765 kV, 60 Hz transposed Line 4 ACSR 1,413,000 cmil, 45/7 RoboLink cond per phase spacing (14m) diameter cond (3.625 cm) and



GMR = 1.439 cm (400 km) long (Lossless Line)

a)

$$Z_C = \sqrt{\frac{L}{C}}$$

$$GMD = \sqrt[3]{(14)(14)(28)} = 17.63\ m$$

$$GMR = 1.09\sqrt[4]{45^3 \times 1.439} = 0.2075\ m$$

$$L = 0.2\ln\left(\frac{GMD}{GMR}\right) = 0.2\ln\left(\frac{17.63}{0.2075}\right) = 0.8885\ mH/km$$

$$GMR_c = 1.09\sqrt{45^3 \times \frac{3.625}{2}} = 0.2198\,\text{m}$$

$$C = \frac{0.0556}{\ln\left(\frac{GMD}{GMR}\right)} = 0.01268\,\mu F/km$$

$$Z_c = \sqrt{\frac{0.8885 \times 10^{-3}}{0.01268 \times 10^{-6}}} = 264.7\,\Omega$$

$$\beta = \omega\sqrt{LC} = 2\pi \times 60\sqrt{0.8885 \times 10^{-3} \times 0.01268 \times 10^{-6}}$$

$$= 0.001265\,\text{rad/km}$$

$$\beta l = 0.001265 \times \frac{180^\circ}{\pi} \times 400$$

$$= 29^\circ$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{0.001265} = 4967\,\text{km}$$

$$SIL = \frac{765^2}{Z_c} = \frac{V_{LL}^2}{Z_c} = 2210.89\,\text{MW}$$

$$A = \cos(\beta l) = \cos(29^\circ) = 0.8746$$

$$B = j Z_c \sin(\beta l) = j(264.7)\sin(29^\circ) = j\,128.33\;\Omega$$

$$C = j\frac{1}{Z_c}\sin(\beta l) = j\,0.00183\;S$$

$D = A = 0.8746$

b) $V_S = A V_R + B I_R$ → this equation in ph-n form only

$V_R = \frac{735}{\sqrt{3}} = 424.35 \angle 0° \text{ kV}$

Fp = 0.8 lagging

$I_R = \frac{2000 \times 10^6}{\sqrt{3} \times 735 \times 10^3} = 1.571 \text{ kA} \angle -36.87$

$\cos^{-1}(0.8) = 36.87°$

$|V_{S(L-L)}| = \sqrt{3}(518.86) = 896.96 \text{ kV}$

$V_S = (0.8746) 424.35 + j 128.33 * 1.571 \angle -36.87$

$= 518.86 \angle 18.15 \text{ kV}$

$I_S = C V_R + D I_R$

$= j 0.00183 * 424.35 \angle 0° + 0.8746 * 1.57 \angle -36.87°$

$= 1.1 \angle -2.46$

$18.15 - (-2.46) = 20.6°$

$P_{F_S} = \cos(20.6) =$

$S_{3\phi \text{ sending}} = \sqrt{3} * 896.96 \angle 18.15 * 1.1 \angle 2.46$

$=$

any value of voltage given is Line to Line

$S_{s(3\phi)} = 3 V_s I_s^*$

$= 3 * 518.86 \angle 18.15 * 1.1 \angle 2.46$

$= 1709.3 \angle 20.6$ MVA

$= 1600$ MW $+ j\, 601.59$ MVAr

$V_R = \dfrac{V_{R(NL)} - V_{R(FL)}}{V_{R(F.L)}}$

$= \dfrac{\frac{896.96}{0.8746} - 735}{735} = 39.53\%$

c)

$\begin{pmatrix} V_s \\ I_s \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix}$

$AD - BC = 1$

$\begin{pmatrix} V_R \\ I_R \end{pmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$

$V_R = D V_s - B I_s$

$V_s = \dfrac{765}{\sqrt{3}} = 441.67 \text{ kV} \angle 0°$

$$S_s = \sqrt{1920^2 + 1600^2} = 2011.57 MVA \angle 17.35$$

$$S_{1\phi} = V * I^*$$

$$= \frac{S^*}{V^*} = \frac{(2011.57/3) \times 10^6 \angle -17.35}{441.67 \angle 0°}$$

$1.518 kA \angle -17.35$

$$V_R = DV_S - BI_S = 377.2 \angle -29.5 kV$$

$$|V_{R_{L.L}}| = \sqrt{3}(377.2) = 653.329 kV$$

$$I_R = -CV_S + AI_S = 1.749 kA \angle -43.55$$

$$S_{R(3\phi)} = 3 V_R I_R^* = 1978.86 \angle 14 MVA$$

$$= 1920 MW + j 479.2 MVAr$$

Solution of last example (cont)

lecture 17

d) V_s, I_s, P_{FS}, S_s with $R_L = 264.5\,\Omega$ and $V_R = 735\,kV$

$V_S = A V_R + B I_R$

$V_R = \frac{735}{\sqrt{3}} = 424.35 \angle 0^\circ$ kV (ph-n)

$I_R = \frac{V_R}{R} = \frac{424.35 \times 10^3}{264.5} = 1604.3478 \angle 0^\circ$

$V_s = A V_R + B I_R = 424.42 \angle 29.02^\circ$ kV

$|V_{s_{L-L}}| = \sqrt{3} * 424.42 = 735.12$ kV

$I_s = C V_R + D I_R = 1604.04 \angle 28.98^\circ$ A

$P_{f_s} = \cos(29.02 - 28.98) = 0.999 \simeq 1$ unity power factor

$S_{3\phi} = 3 V_s I_s^*$

$= 3 (424.42 \angle 29.02^\circ)(1604.04 \angle -28.98^\circ)$

$= 2042.4 \angle 0.04$ MVA

$= 2042.4$ MW $+ j\,1.4$ MVAr

$$V.R = \frac{\frac{735.12}{0.8746} - 735}{735} \times 100 = 14.36\ \%$$

A

prob 5-18

power system studies on an existing system have indicated that 2400 MW are to be transmitted for distance of 400 km, the voltage level being considerd, in clude 345 kV, 500 kV and 765 kV for a preliminry design based on the practical line, loadability you may assume the following Surge impedence

345 kV	$Z_c = 320\ \Omega$
500 kV	$Z_c = 290\ \Omega$
765 kV	$Z_c = 265\ \Omega$

$$V.R = \frac{\frac{735.12}{0.8746} - 735}{735} \times 100 = 14.36\ \%$$

A

prob 5-18

power system studies on an existing system have indicated that 2400 MW are to be transmitted for distance of 400 km, the voltage level being considered, in clude 345 kV, 500 kV and 765 kV for a preliminary design based on the practical line, loadability you may assume the following surge impedence

345 kV	$Z_c = 320\ \Omega$	765 kV	$Z_c = 265\ \Omega$
500 kV	$Z_c = 290\ \Omega$		

The line wave length may be assumed to be 5000 km, the practical line loadability may be based on a load angle of 35°, assume $|V_S| = 1.0$ p.u and $|V_R| = 0.9$ p.u. Determine the number of 3-phase transmission cct's required for each voltage level, each T. transmission tower may have up to 2cct's

To limit the corona loss, all 500kV line must have at least 2 conductor/phase and all 765kV lines must have at least 4 conductors/phase, The bundle spacing is 45cm, the cond size should be such that the line would be capable of carrying current corresponding to at least 5000MVA

جهد عالي ≡ دوائر أقل

ال... تقدر تنقلها ... [illegible]

SIL استخدم لتعرف

$$P_{3\phi} = \frac{|V_s|_{pu} * |V_R|_{pu} * SIL}{\sin\left(\frac{2\pi l}{\lambda}\right)} \sin\delta$$

345kV

$$SIL = \frac{kV_{L,L}^2}{Z_c}$$

$$= \frac{345\,kV^2}{320} = 371.95\,MVA$$

$$P_{3\phi} = \frac{1 * 0.9 * 371.95}{\sin\left(\frac{2\pi 400}{5000} \times \frac{180}{\pi}\right)} \sin(35)$$

$$28.8^\circ$$

$$\simeq 400\,MW$$

$$\#\ \text{of cct's} = \frac{2400}{4} = 6\ \text{circuits}$$

$$\#\ \text{of twers} = \frac{6}{2} = 3\ \text{twers}$$

ex: $V_s = +3\% = 1.03$ pu

103% $V_s = -4\% = 0.96$ pu

96%

500 kV

$$SIL = \frac{500^2}{290} = 862.07 \text{ MVA}$$

$$P_{3\phi} = \frac{1 * 0.9 * 862.07}{\sin(28.8)} \sin(35)$$

$$= 923.3 \text{ MW}$$

\# of circits $= \frac{2400}{923.3} = 2.6 \Rightarrow$ 3 circits

\# of towers $= \frac{3}{2} = 1.5 \Rightarrow$ 2 towers

765 kV

$$SIL = \frac{765^2}{265} = 2208.4 \text{ MVA}$$

$$P_{3\phi} = \frac{1 * 0.9 * 2208.4}{\sin(28.8)} \sin(35) = 2365.2 \text{ MW}$$

\# of circuits = 1 cct

\# of towers = 1 tower

So 765 is the best one

$$I = \frac{5000}{\sqrt{3} \times 765} = 3773.5 \text{ A /phase}$$

$$I = \frac{3773.5}{4} = 943.38 \text{ A /conducter}$$

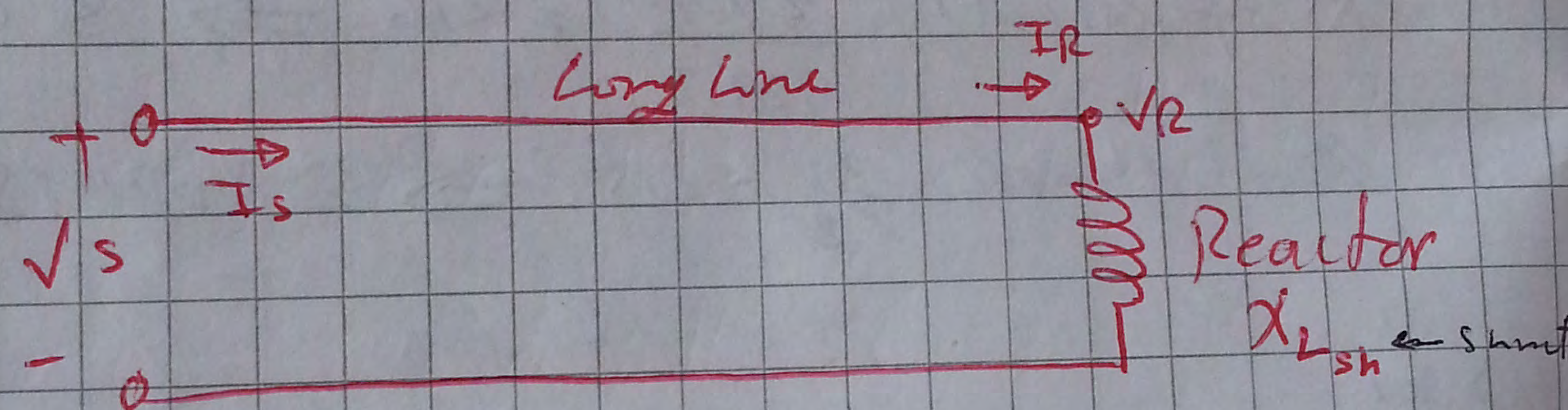
From table se which cond have this value

وظيفته كيف نضيف X_2 أو X_1 * إضافة shunt capacitor كمعالجة الفـ...
زود تكلفة
* نضيفو T.L (مكلف جداً) بلا يتقسم...

lecture 18

Line Compensation :-

Shunt reactor ↓ V — Light Load (no load) so voltage increase
Shunt capacitor ↑ V — (Loaded line) Low voltage so add capacitor



$$I_R = \frac{V_R}{jX_{L_{sh}}} \quad -①$$

$$V_s = A V_R + B I_R$$

Loss less

$$= \cos(\beta l) V_R + j Z_c \sin(\beta l) I_R \quad -②$$

sub ① in ②

$$V_s = \left[\cos(\beta l) + \frac{Z_c}{X_{L_{sh}}} \sin(\beta l)\right] V_R \quad -③$$

Assume V_R and V_S are in phase

So the power through T.L is zero

From (3)

$$\boxed{X_{L_{sh}} = \frac{\sin(\beta l)}{\frac{V_S}{V_R} - \cos(\beta l)} Z_C} \quad - (6)$$

For $V_S = V_R$

$$X_{L_{sh}} = \frac{\sin(\beta l)}{1 - \cos(\beta l)} Z_c$$

To find ~~the~~ relation between I_S and I_R

$I_s = C V_R + D I_R$

$$= J \frac{1}{Z_c} \sin(\beta l) V_R + \cos(\beta l) I_R \quad - (4)$$

sub (1) in (4)

$$V_S = \left[-\frac{1}{Z_c} \sin(\beta l) X_{L_{sh}} + \cos(\beta l) \right] I_R \quad - (5)$$

sub ⑥ in ⑤

$$I_S = -I_R$$

at mid span
(T.L ال (منتصف))
$I = 0$

$$V_m = \frac{V_R}{\cos\left(\frac{\beta l}{2}\right)}$$

mid point

in lecture 13

Example 8 For T.L of EX2 calculate

ⓐ the receiving end voltage when line is terminated in an open circuit and is energized with 500 kV at the sending end

ⓑ Determine the reactance and MVAr of 3ϕ shunt reactor to be installed at the receiving end to keep the no load receiving end voltage at the rated value

$V_s = 500\,kV$

open cct $\Rightarrow I_R = 0$ (no load)

$Z_c = 290.43\,\Omega$

$\beta l = 21.64$

the receiving end voltage

$$V_{R(NL)} = \frac{V_s^{\,ph\text{-}n}}{A} = \frac{288.675 \times 10^3}{0.9295} = 310.57\,kV \text{ (ph-n)}$$

$$V_s = \frac{500}{\sqrt{3}} = 288.675\,kV$$

$$A = \cos(\beta l) = 0.9295$$

$$\left| V_{R(NL)} \right|_{L\text{-}L} = \sqrt{3}\,(310.57) = 537.9\,kV$$

$$X_{2_{sh}} = \frac{\sin(21.64)}{1 - \cos(21.64)} \times 290.43$$

$$= 1519.5\,\Omega$$

$$Q = \frac{V_{LL}^2}{X} = \frac{500^2}{1519.5} = 164.53\,MVA_r$$

For 3ϕ

عادة نقطعو الـ reactor ما يتعبوا الـ load صفر و no load
capacitor -- -- -- كبير

lecture 19

Shunt capacitor Compensation

$$P_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{|B|}\cos(\theta_B-\delta) - \frac{|A||V_{R(L.L)}|^2}{|B|}\cos(\theta_B-\theta_A)$$

$$\rightarrow P_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{X'}\sin\delta \qquad \text{Lossles Line}$$

$$Q_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{|B|}\sin(\theta_B-\delta) - \frac{|A||V_{R(L.L)}|^2}{|B|}\sin(\theta_B-\theta_A)$$

$$\rightarrow Q_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{|B|}\cos(\delta) - \frac{|V_{R(L.L)}|^2}{X'}\cos(\beta l)$$

Lossless Line

$$(X' = B)$$

Series capacitor Compensation :-

1) Are connected in series with the Line

2) Are located at the mid point of the Line

used for :

1) are used to reduce the series reactance

Percentage Compensation $= \frac{X_{C_{ser}}}{X}$

between The Load and supply point

2) Improve Steady state and transient stability

3) More economical loading

4) Minimum Voltage dip on Load buses

Example: A transmission line in Ex (5.5) → lecture (13) supplies a load of 1000 MVA, 0.8 p.f lagging at 500 kV, a) Determine the MVAr and the capacitance of the shunt capacitor to be installed at the receiving end voltage at 500 kV when the line is energized with 500 kV at the sending end

b) only series capacitor are installed at the mid point of the line providing 40 % compensation, find the sending end voltage and V.R

Lagging = inductive Load
leading = capacitive Load

$Z_c = 290.43\ \Omega \quad , \quad \beta l = 21.64^\circ$

$\cos^{-1}(0.8) = 36.87^\circ$

$S_r = 1000 \angle 36.87^\circ = 800\ MW + j\ 600\ MVAr$

a)

$B = X' = Z_c \sin(\beta l) = 290.43 * \sin(21.64)$

$= 107.11\ \Omega$

$$P_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{X'} \sin\delta$$

$$800\ MW = \frac{(500k)(500k)}{107.11} \sin\delta$$

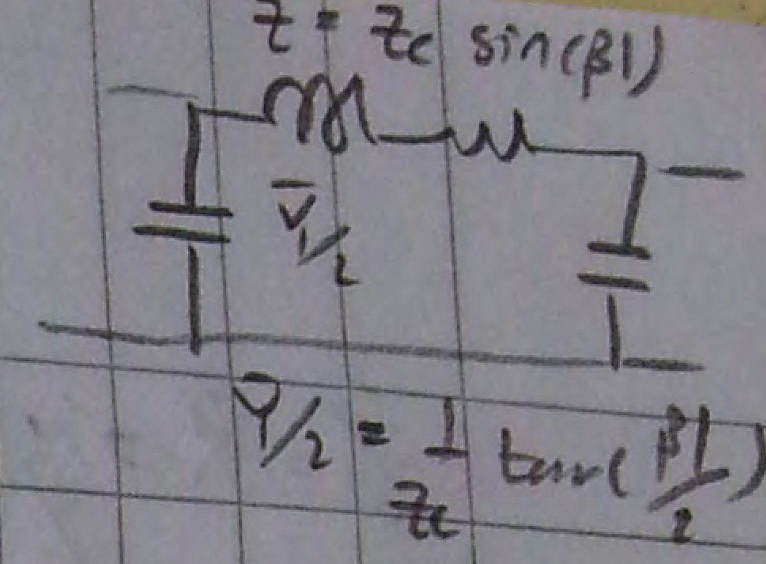
$\delta = 20.04^\circ$

$$Q_{R(3\phi)} = \frac{|V_{S(L.L)}||V_{R(L.L)}|}{|B|} \cos(\delta) - \frac{|V_{R(L.L)}|^2}{X} \cos(\beta l)$$

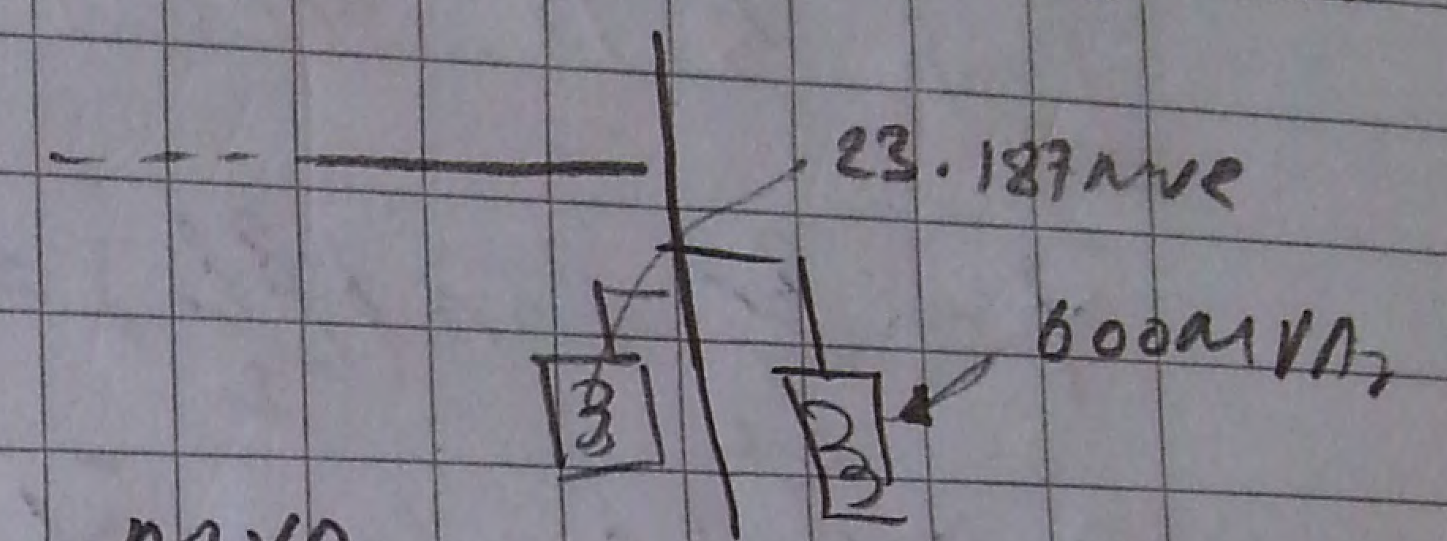
$$= \frac{(500k)(500k)}{107.11} \cos(20.04) - \frac{500^2}{107.11} \cos(21.64)$$

$= 23.187\ MVAr$

+ve يعني (leading) P_f لما



at the reciever end



The required capacitor MVAr

P_f (lagging) $= j23.187 - j600 = -j576.85$ MVAr

$$X_c = \frac{kV_R^2}{Q} = \frac{500^2}{576.85} = 433.38\,\Omega$$

$$C = \frac{1}{\omega X_c} = \frac{1}{2\pi \times 60 \times 433.38} = 6.1\,\mu f$$

b)

$$40\% = \frac{X_{C_{ser}}}{X} = \frac{X_{C_{ser}}}{107.11} \Longrightarrow X_{C_{ser}} = 42.84\,\Omega$$

ملاحظة مهمة (باستخدام ال compensation هم (A) و (B) هتتغير

$V_s = AV_R + BI_R$

$A = 1 + \frac{\bar{Z}\bar{Y}}{2}$, $B = \bar{Z}$, $C = \bar{Y}(1 + \frac{\bar{Z}\bar{Y}}{2})$

$D = A$

$S = 3 V_R I^*$

$\bar{Z} = \bar{X} = j107.11 - j42.84 = j64.27\,\Omega$

$\bar{Y} = \frac{2}{Z_c} \tan\left(\frac{\beta l}{2}\right) = \frac{2}{290.43} \tan\left(\frac{21.04^\circ}{2}\right)$

$\bar{Y} = 0.001316\ S$

$A = 1 + \frac{\bar{Z}\bar{Y}}{2} = 0.9577$

$B = \bar{Z} = j64.27\,\Omega$

$V_{R_{ph-n}} = \frac{500k}{\sqrt{3}} = 288.675\ kV \angle 0^\circ$

$I_R = \frac{1000 \angle -36.87}{3 \times 288.675 \angle 0} = 1.155 \angle -36.87\ kA$

$V_{s_{ph-n}} = 326.4 \angle 10.47\ kV$

$|V_{s(L-L)}| = \sqrt{3}\,(326.4) = 565.4\ kV$

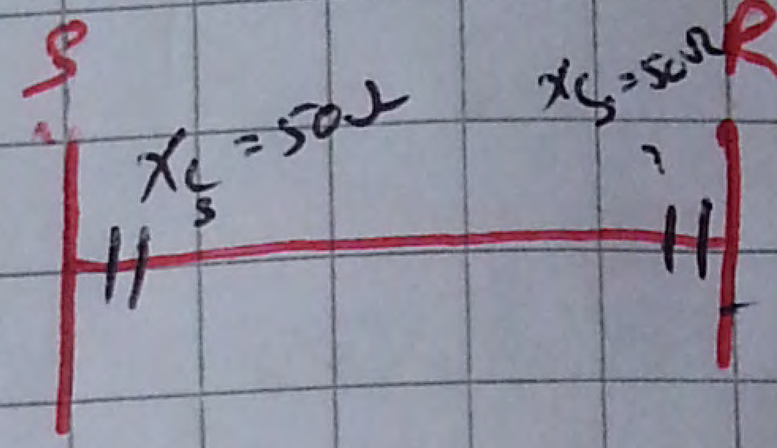
$\% VR = \frac{V_{R(NL)} - V_{R(FL)}}{V_{R(FL)}} \times 100$

$V_{R(NL)} = \frac{V_s}{A} = \frac{565.4}{0.9577} = 590.37\ kV$

$$\%VR = \frac{590.37 - 500}{500} \times 100 = 18\%$$

lecture (20

Prob 5-15 saadat



1000 MVA

$P_f = 0.8$ lagging

500 MW

$A = D = 0.86 + j\,0.0$

$B = 0 + j\,130.2\ \Omega$

$C = j\,0.002$ ℧

a) V_s, I_s, P_{fs}, S_s and V_R

b) by adding series capacitor at the two ends

Find $A'B'C'D'$ constant

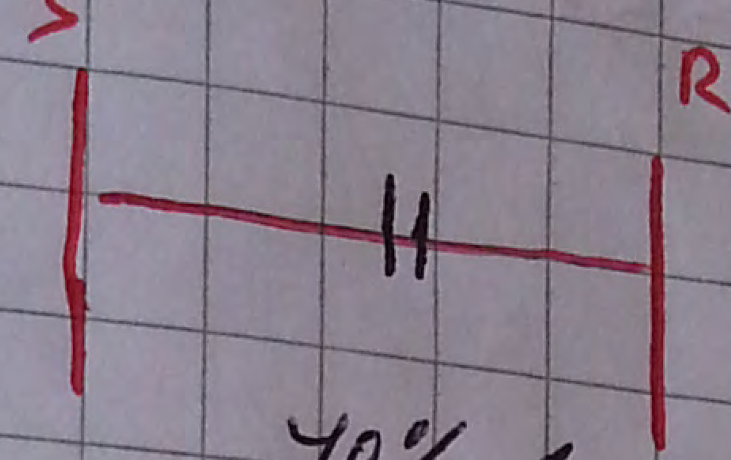
$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 1 & -j50 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 0.86 & j130.2 \\ j\,0.002 & 0.86 \end{bmatrix} \begin{bmatrix} 1 & -j50 \\ 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.96 & j39.2 \\ j\,0.002 & 0.96 \end{bmatrix}$$

$$V_{s\,new} = A' V_s + B' I_R$$

Prob 5-12 Saadat

$B = X' = 128.33\ \Omega$



40% compensation

$\beta l = 29$

$Z_c = 264.7\ \Omega$

$$40\% = \frac{X_{c\ series}}{X'}$$

$$X_{c_s} = 0.4 \times 128.33 = 51.33\ \Omega$$

$$C = \frac{1}{\omega X_c} = 51.67\ \mu F$$

$$\bar{Z} = j(128.33 - 51.33) = j\,77\ \Omega$$

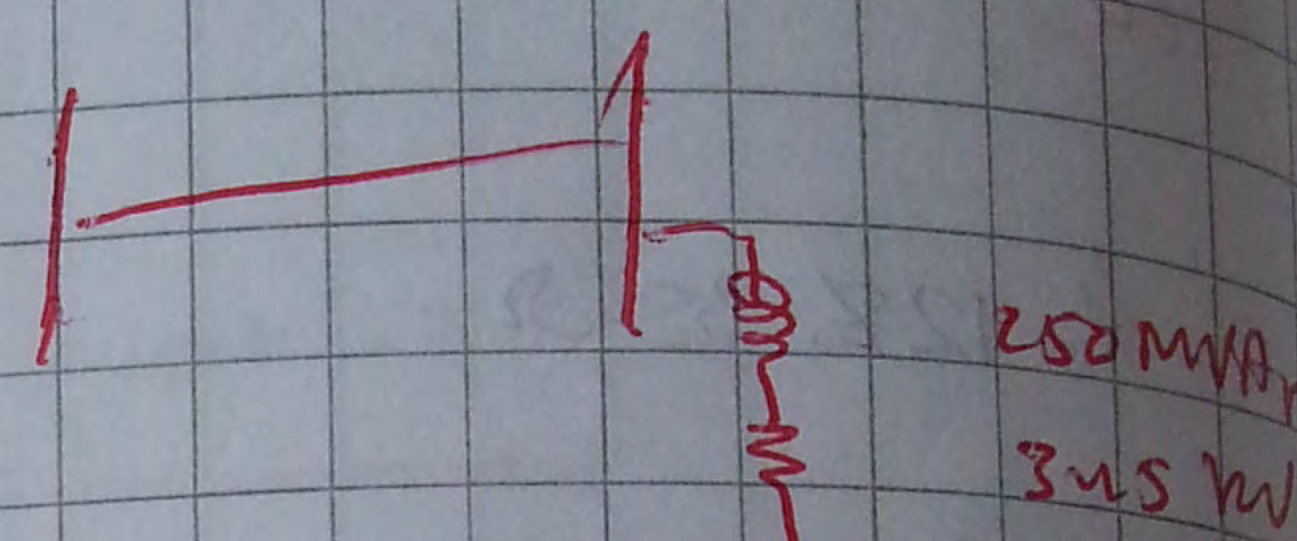
$$\bar{Y} = j\frac{2}{Z_c}\tan\left(\frac{\beta l}{2}\right) = j\frac{2}{264.7}\tan\left(\frac{29}{2}\right) = j\,0.001954$$

$$A = 1 + \frac{(j77)(j\,0.00195)}{2} = 0.92476$$

$$B = \bar{Z} = j\,77\ \Omega$$

$$C = \bar{Y}\left(1 + \frac{\bar{Z}\bar{Y}}{4}\right) = 0.00188$$

prob 6-25 Stev



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.818\angle 1.3 & 172.2\angle 84.2 \\ 0.001933\angle 90.4 & 0.818\angle 1.3 \end{bmatrix}$$

$$X_L = \frac{345^2}{250} = 476.1\angle 90$$

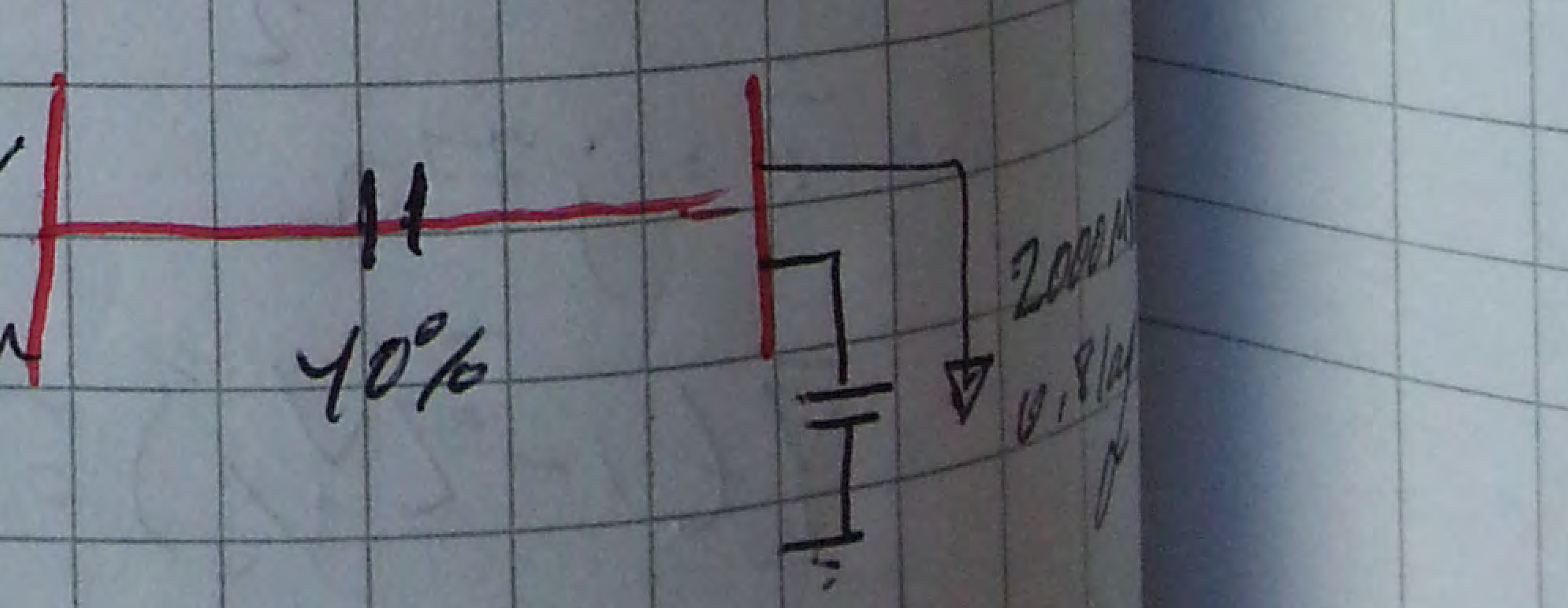
$$B_L = \frac{1}{X_L} = \frac{1}{476.1\angle 90} = 0.0021\ \angle -90 = -j0.0021$$

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} 1 & 0 \\ -j0.0021 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1.178\angle -0.88 & 172.2\angle 84.2 \\ 0.000217\angle 83.25 & 1.178\angle -0.88 \end{bmatrix}$$

prob

Find total MVAr and capacitance of series and shunt capacitor ~~plan~~ to keep $V_R = 735$ kV where $V_S = 785$ kV where $X' = 128.33\,\Omega$



$$P_{R_{3\phi}} = \frac{|V_S||V_R|}{X}\sin\delta$$

Line-Line

$$Q_{R_{3\phi}} = \frac{|V_S||V_R|}{|B|}\cos\delta - \frac{|V_R|^2}{X}\cos(\beta l)$$

$$2000\angle 36.869^\circ = 1600 + j1200$$

$$X_{new} = 128.33 - 0.4(128.33) = j77\Omega$$

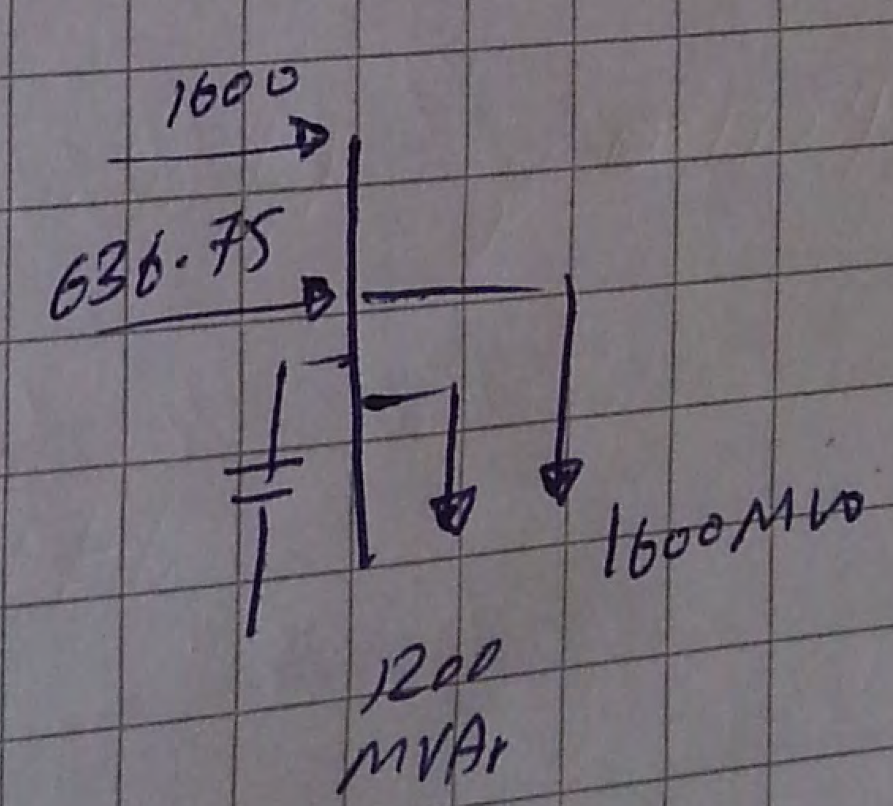
$$1600 = \frac{(765)(735)}{|j77|}\sin\delta$$

$$\delta = 12.656^\circ$$

$$Q_{R_{3\phi}} = (765)(735)\cos(21.656) - \frac{(735)^2}{77}\cos(29)$$

$$= 636.75 \text{ MVAr}$$

$$j636.75 - j1200 = -j563.25 \text{ MVAr}$$



$$X_C = \frac{735^2}{563.25} = -j959.12\Omega$$

لحساب $I_{R_{new}}$

$S_R = 1600 + j\,636.75$

$$I_{R_{new}} = \frac{S^*_R}{3\,V^*_R}$$

see problem 6.16 step (8)